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4. cold storage
5. dry storage
6. field rations

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ESTABLISHING OPTIMUM CONDITIONS FOR STORAGE AND HANDLING OF SEMI- PERISHABLE SUBSISTENCE ITEMS.

A conference sponsored by the

RESEARCH AND DEVELOPMENT DIVISION
OFFICE OF THE QUARTERMASTER GENERAL

Office of The Quartermaster General

Washington, D. C.

3 December 1953

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OFFICE OF THE 'QUARTERMASTER' GENERAL

RESEARCH AND DEVELOPMENT DIVISION

Washington

March 1955

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SURVEYS OF PROGRESS ON MILITARY SUBSISTENCE PROBLEMS

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3. Stability of Dehydrated Eggs
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5. Color in Foods

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SERIES III. FOOD ACCEPTANCE

1. Food Acceptance Testing Methodology

SERIES IV. MILITARY UTILITY OF FOODS

1. Establishing Optimum Conditions for Storage and Handling of Semiperishable Subsistence Items

Opinions expressed in the conference on *Establishing Optimum Conditions for Storage and Handling of Semiperishable Subsistence Items* are those of the individual participants and do not necessarily represent the views or policies of the Department of Defense.

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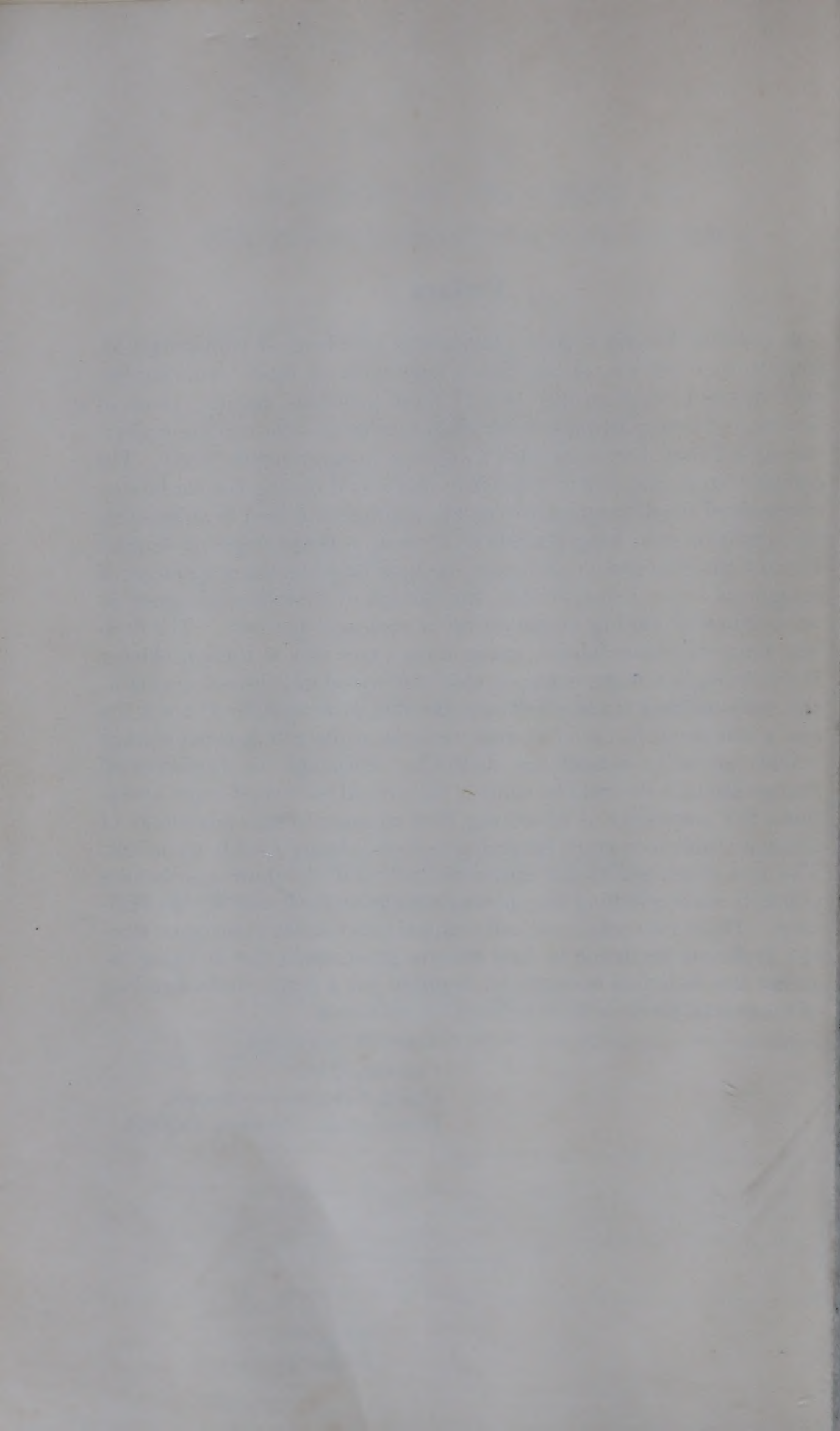


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Preface

A military supply system poses many problems of transportation, storage, distribution, and kitchen preparation of food. This conference devoted itself to only two of these problems, namely, those of storing and transporting semiperishable products—the conference having agreed that there is no such thing as a “nonperishable” food. The results of research and of experience presented during the conference emphasized the difficulties involved in maintaining food in an acceptable condition over long periods of time in military types of storage. Because the distribution of depots has been based on the advantages of a regional type of distribution, the storage of subsistence has not always followed quality conservation or economic patterns. The findings presented stimulated in many ways a new look at these problems. It was brought out, for example, that even a moderate lowering of storage temperatures could effect considerable prolongation of shelf-life and a reduction in turnover requirements while refrigerated storage would markedly extend the shelf-life. Although no fundamental change has been or could be made in the overall pattern of depot operations, the possibility of relocating food storages to take advantage of climatic conditions more favorable to food is being freshly examined. The data developed at this conference will find usefulness as reference points in accomplishing the optimal storage of foods used by the Military. Those who conceived and planned this notable meeting on storage problems pertinent to food deserve great credit for bringing together the technical background required for a better understanding of the overall problem in its military connotations.

JOHN W. MAXWELL
Colonel, QMC
Chief, Subsistence Branch
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Proceedings of the Conference
ESTABLISHING OPTIMUM CONDITIONS FOR STORAGE AND HANDLING OF SEMIPERISHABLE SUBSISTENCE ITEMS

I. INTRODUCTION

Thursday Afternoon Session

3 December 1953

DR. DONALD K. TRESSLER, *Presiding*

Purpose of the Conference

CHAIRMAN TRESSLER:

This conference is being held for the purpose of establishing optimum conditions for storage of what is commonly called semiperishable subsistence items. But let me register early in this conference that, with the possible exception of salt and sugar, there would appear to be no such thing as nonperishable foods. Ration items, in fact, do not retain their quality in storage anywhere near as long as many of us have imagined—even those we have called semiperishable.

Some 15 months ago, as a result of visible signs of deterioration, it was proposed that the large stocks of field rations, then in various Quartermaster depots, be screened for deteriorated items and then be placed in cold storage in order to minimize further losses. But doubt as to the precise storage temperature and humidity for optimum keeping quality and the probable “life” of these rations after removal from cold storage prevented moving immediately into this program. The wrong controls are worse than no controls since refrigeration obviously entails expense.

The Quartermaster Food and Container Institute has recently been studying this problem of the storage life of packaged ration items. For the past 3 years, the Institute has sponsored contract storage studies on the various field rations, notably the C Ration, *without* refrigeration. A year ago, these studies were expanded to determine what advantages may be gained by storing field rations with refrigeration. The purpose of this work, and of companion work in progress at the Institute, is to determine the optimum storage conditions of each ration item under study.

Today you will learn with interest, I believe, through the subsistence studies of Drs. Woodroof and Mitchell that with the possible exception

of salt and sugar, all ration items gradually deteriorate when held at temperatures above 70° F.

Now turning to the immediate business of the day—in this conference we desire to accomplish the following:

(a) call attention to the fact that substantially all subsistence is semiperishable;

(b) point up the many advantages of refrigerated storage of field rations;

(c) indicate the possible hazards which **may** result because of the condensation of moisture on subsistence after removal from a cold room;

(d) indicate how this condensation may be avoided;

(e) review and summarize our present knowledge of the refrigerated storage of field rations;

(f) learn what additional information is required to establish optimum storage conditions for all semiperishable subsistence;

(g) determine the relative cost of dry storage of field rations for a 2-year period followed by "forced issue," and cool storage of these rations for an indefinite period;

(h) consider whether the cool storage of the individual components of field rations is more desirable than the cool storage of the assembled rations;

(i) determine if Industry Advisory Committees should be set up to advise the Quartermaster concerning storage of semiperishable items;

(j) decide whether or not Technical Manual 10-250 needs revision. If so, we should indicate what additional data are required to revise it adequately.

We will now proceed to review for you the available information concerning the rate and extent of deterioration of certain field rations and some of their less stable components.

Our first speaker, Professor Emil Mrak, head of the Food Technology Department, University of California, has long been interested in Quartermaster subsistence problems.

Past and Current Efforts to Increase the Storage Life of Subsistence

EMIL MRAK

Department of Food Technology, University of California

Since my close contact with the Quartermaster Corps during World War II, I have heard continuously of the need to increase the storage life of various items used in rations. This need became so apparent during the latter part of the war that it was, in part at least, respon-

sible for the organization of the Quartermaster Food and Container Institute Committee on Food Research, many of the functions of which are now conducted by the NRC Committee on Foods. This Committee, charged with the responsibility of developing a research program concerned with the improvement of rations, soon learned that some of the principal factors determining acceptability were, to a major extent, factors of stability and, to a somewhat lesser extent, of utility. With this in mind, a research program was developed with the ultimate aim of creating ration items that would remain stable for a period of 6 months at 100° F. and even 120° F., and be easy to handle, store, and distribute. The basic information available at the time was not sufficient to enable anyone to predict the outcome of such studies. Furthermore, the war was on and requests and needs of the Armed Forces were not questioned.

As a result of this program, an immense amount of information concerning the "browning reaction," fat deterioration, pectin, texture, flavor, color, and vitamin changes were obtained. This information has had many applications, but it has also emphasized the fact that the prolongation of storage life is complicated and cannot be solved by any one procedure.

In my opinion, the men at the Quartermaster Food and Container Institute have done an excellent job not only in accumulating information but also in applying the information available to the development and packaging of ration items. Tremendous improvements have been made in the last 10 years, but still we hear of ration items deteriorating in storage. I am afraid that developing a completely stable ration is something like trying to develop an automobile capable of holding up for 6 years at 70 miles an hour on 1900 roads. Automobiles and roads have both improved with time. Fuel has also improved. Development of the modern automobile has resulted from a several-pronged attack—not just one. The same idea applies to ration items. If we are to increase the stability, and hence the acceptability, of ration items, then we must consider all factors involved, including manufacture, storage, distribution, and even inspection. We must also take advantage of the improvement made in foods generally.

There appears to be a rather general feeling that canned, dried, pickled, and chemically preserved foods are stable because they do not ordinarily show any signs of rot or putrefaction and are free of obvious microbial growth and foul odors. There is also the feeling that the only measure of a spoiled food is whether or not it will cause illness if ingested.

Food spoilage may be quite subtle and certainly in the early stages escape even the careful scrutiny of an inspector, unless he is well

trained in food technology. Microbial spoilage is no longer the serious problem it was even 20 years ago. The more serious types of spoilage today may be classified as chemical and entomological. The latter is concerned with insect infestation, which of course renders a food inedible from an aesthetic point of view. Chemical deterioration includes a number of types of spoilages. A few examples are as follows:

Browning reaction. This type of spoilage results in darkening or "browning" of the product, a loss in flavor, a decrease in certain nutrients, and undesirable changes in taste. The natural flavors disappear and off-tastes develop. In addition, there may be undesirable changes in texture and even the production of toxic substances. Some of the commodities that undergo this type of deterioration are dried fruits and vegetables, powdered eggs and milk, fruit juice concentrates, certain beverages, jams, jellies, canned bread, certain canned vegetables, meat items, and many other foods.

Fat deterioration. Fats undergo changes resulting in the production of off-odors and taste, loss of nutritive value, and perhaps the production of toxic substances. A few items so affected are biscuits, cookies, prepared mixes, ice cream powder, dried whole milk, etc.

Changes in texture. Several types of chemical changes may take place to cause texture changes. In dried cranberries changes in the pectin molecule may occur to the extent that the gelling power is decreased or lost. In other cases, the product may actually toughen. Dried apricots sometimes become brittle.

Color changes. It is well known that the naturally occurring colors of many food items undergo undesirable changes during storage. The anthocyanin pigments of strawberry jam gradually disappear with storage. At the same time, browning takes place with the result that the jam becomes brown or black rather than red. Canned items such as berries, prunes, and beets undergo color changes during storage under adverse conditions. There are many other examples.

Staling reaction. I doubt that the mechanism of this "reaction" is even partly understood. At any rate it does result in an undesirable change in the texture of items such as canned bread.

Vitamin changes. Frequently, there is a gradual loss in vitamins during storage. This is true in practically all foods that have been studied.

These examples will serve to prove that the problem of chemical spoilage of foods is an important one. It is so important that, in one way or another, it involves nearly all the foods we are concerned with.

At this point, it would be well to express my astonishment at the possibility of the Army perpetuating the idea of semiperishable goods. The sooner the Army forgets this the better. All foods, except salt and perhaps sugar, are perishable. The point I wish to

emphasize is, no matter how perfect a food may be when developed by the Food and Container Institute, it is bound to be perishable and can be ruined by improper storage and handling.

One wonders what might be done about the situation. The following are feasible and constructive suggestions:

1. Produce and procure items with the best storage life possible. The Quartermaster Corps is already doing an excellent job in this direction.

2. Store food items under the most favorable conditions possible. This means the use of warehouses where the mean average temperature is low and the use of cold storage. It also means operating the warehouse in a manner to take advantage of cool night air in areas where this is possible.

3. Use distribution practices whereby the oldest items will be moved out first and at the same time be exposed to a minimum of abuse due to high temperatures during shipment.

4. Require periodic surveillance inspection of items by trained food technologists so that the first signs of incipient chemical spoilage can be detected with the view that these items would be utilized as soon as possible.

The vast amount of work done by the Quartermaster Corps has shown conclusively that storage temperature is the most important single factor influencing the storage life of food items as packed today. It is encouraging to note that certain segments of the industry are applying this information. For example, some fig packers are now holding the better grades of dried figs in cool storage. Warehousing in cooler areas and the use of attic fans for night cooling are becoming more common.

In view of these changes in industry and because of the several recommendations of the Subcommittee on Fruits and Vegetables of the NRC Committee on Foods that the effect of warehousing conditions on rations be studied, it was considered desirable to obtain some first-hand information on temperature changes in three locations and the storage life of certain items stored at these places. Such a project was started in collaboration with the Western Utilization Research Branch using dried fruit and vegetable items stored at Oakland Stockton, and White Mountain, California. Oakland was chosen because of its nearness to the Coast, Stockton because of its location in the warm central valley, and White Mountain because of the altitude and low mean average temperature. An indication of the temperature variations occurring at these three places during the years 1952-53 are shown in table 1.

Table 1. Warehouse temperatures in California

Location	25 June through 9 December 1952			25 June 1952, through 14 August 1953		
	Hours above at selected ° F.					
	80°	85°	90°	80°	85°	90°
White Mountain-----	0	0	0	0	0	0
Oakland-----	81	45	0	186	45	0
Stockton-----	1, 161	535	161	1, 798	808	312

It is apparent that Oakland and White Mountain are far superior to Stockton from the standpoint of temperature. If it is assumed that the rate of deterioration doubles with every 18° F. rise in temperature, it is apparent that the rate of storage deterioration should be far greater at Stockton than at Oakland or White Mountain.

I was very surprised to find, after this paper was prepared, that the Quartermaster Corps already has a great deal of depot warehouse temperature data. This information is quite extensive and an excellent point of departure for future planning.

Summary

1. Practically all foods are perishable, particularly from the standpoint of chemical deterioration.

2. The improvement of rations and the prolongation of the storage life of rations depends not only on the production of a superior item, but also on *storage conditions, handling and distribution*, and surveillance inspection.

3. Serious consideration should be given to the possibility of using carefully selected storage places, night cooling with attic fans or some other cooling device, and the use of cold storage.

4. Foods start to undergo chemical deterioration immediately after packing. This continues during storage and handling until consumed. The rate at which this deterioration takes place depends on the temperature during storage and handling.

II. RATE AND EXTENT OF DETERIORATION OF PACKAGED RATIONS DURING STORAGE AND TRANSPORTATION

CHAIRMAN TRESSLER:

Dr. Mrak told you that we were doing a great deal on storage of subsistence at the Food and Container Institute. That is certainly true, and we have sponsored a great deal of work to help to solve storage problems. The leader in these storage studies is Dr. J. H. Mitchell, Jr., who will tell us something about the work that he has been supervising.

Stability Studies on Rations at the QMFCI

J. H. MITCHELL, JR.

Stability Division, Quartermaster Food and Container Institute for the Armed Forces

Of primary concern to the Quartermaster Corps is the quality of the food which it supplies to the man in uniform. No matter how high the initial quality, the consumer does not receive real benefit if the food is not stable during storage. The ideal food for use by the Armed Forces would be unaffected by temperatures ranging from sub-zero to well over 100° F. for long periods of time; however, such stability is impossible to achieve in a great many food items. Stability studies of rations under controlled conditions and examination of stockpiled rations have shown that virtually all foods deteriorated if stored long enough under conditions found in some of the storage depots. Deterioration may be moderate or severe, depending upon the nature of the food item.

From storage studies in our laboratories over the last 3 years we now have definite proof that almost all canned and dehydrated foods keep well at 40° F. and in many instances at 70° F. At 100° F., however, a temperature often reached in common warehouse storage, deterioration was rapid—in some cases occurring within 12 months.

We have planned our storage studies to take advantage of both chemical examination and acceptance testing. By chemical analysis we try to find out what changes are taking place in the food item.

The results often are related to changes in acceptability and we hope to develop correlations which will aid in judging food quality.

I have selected data from examination of a variety of ration food products in order to illustrate what happens during storage at several temperatures.

Figure 1 shows some of the changes which occur in dehydrated white potatoes in storage for 2 years at 40°, 70°, and 100° F. It is obvious that at 100° F. the acceptability, shown by ratings on an acceptance scale from 1 to 9, fell rapidly, and the potatoes were no longer suitable for use after approximately 8 months. At 40° and 70° F., however, changes in acceptability were much slower. Chemical analysis indicated that browning, measured by the saline fluorescence, is a serious type of deterioration in this product, and it is obvious that a high degree of correlation exists between this chemical measurement and acceptability.

Figure 2 shows what happened to sandwich-type cookies. In every type of test made, it may be seen that changes at 100° F. were more severe than at 40° and 70° F. At the end of 6 months at 100° F., these cookies had reached the borderline of acceptability. Since the cookies had not changed significantly in acceptability after 12 months at 70° F., they were not tested for acceptability at 40° until 24 months had passed. At the end of this time they still received a high rating, practically unchanged from the original.

Figure 3 shows another cereal item, crackers used in the C Ration. Since these crackers were packed for this study in cans by themselves, there was no chance for moisture or flavor transfer. The sharp rise in peroxide value, indicating fat oxidation, shows that as a possible cause for the rapid drop in acceptability at 100° F. The evidence for fat oxidation suggests the use of more stable shortenings, antioxidants, and nitrogen packing, as well as low storage temperatures, as cures for the decline in acceptability of these crackers in storage.

These crackers packed separately were compared with crackers packed in the B-units of the C Ration. It was found that they differed significantly in acceptability when packed with coffee and cocoa, due to transfer of flavor.

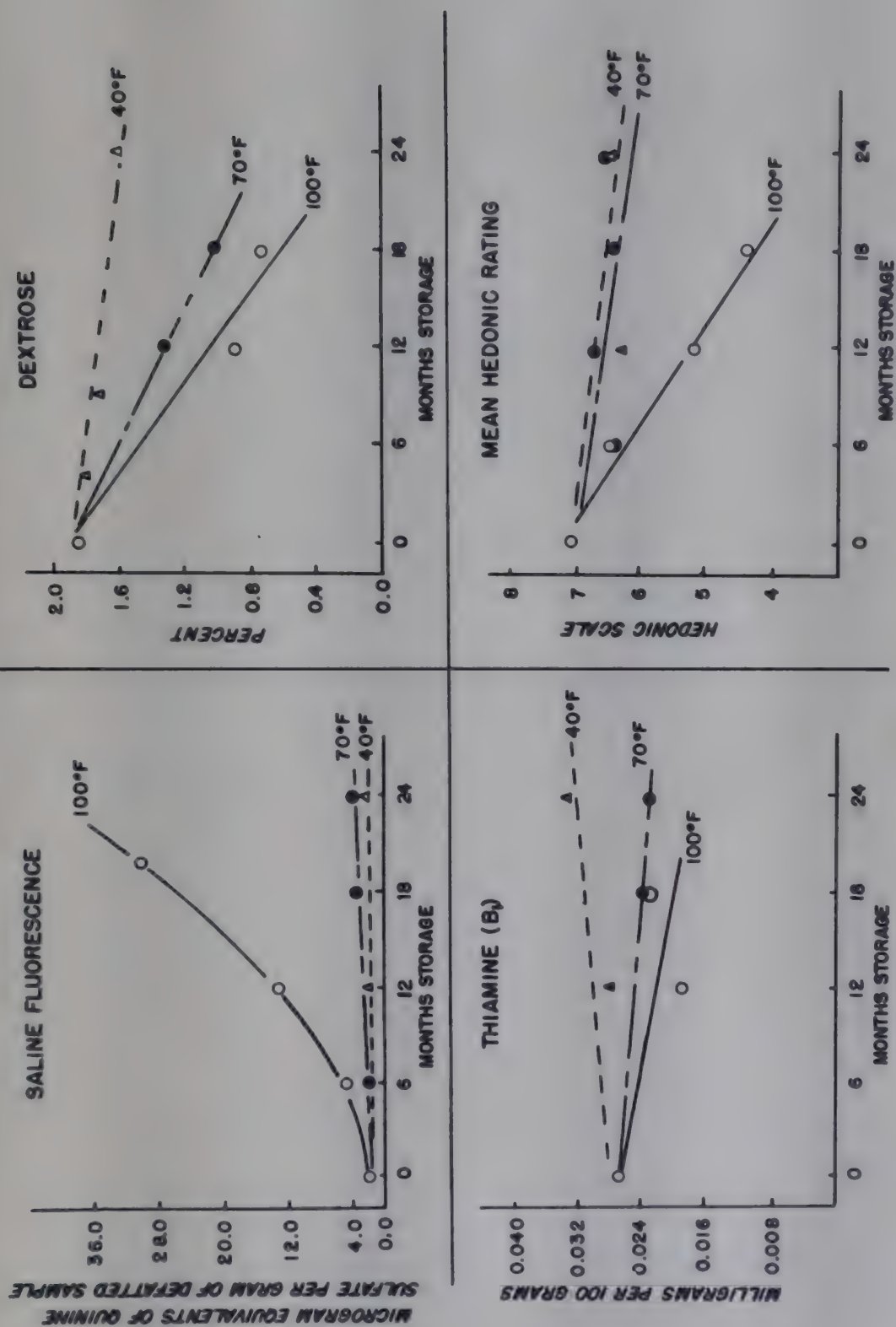


Figure 1.

SANDWICH COOKIE

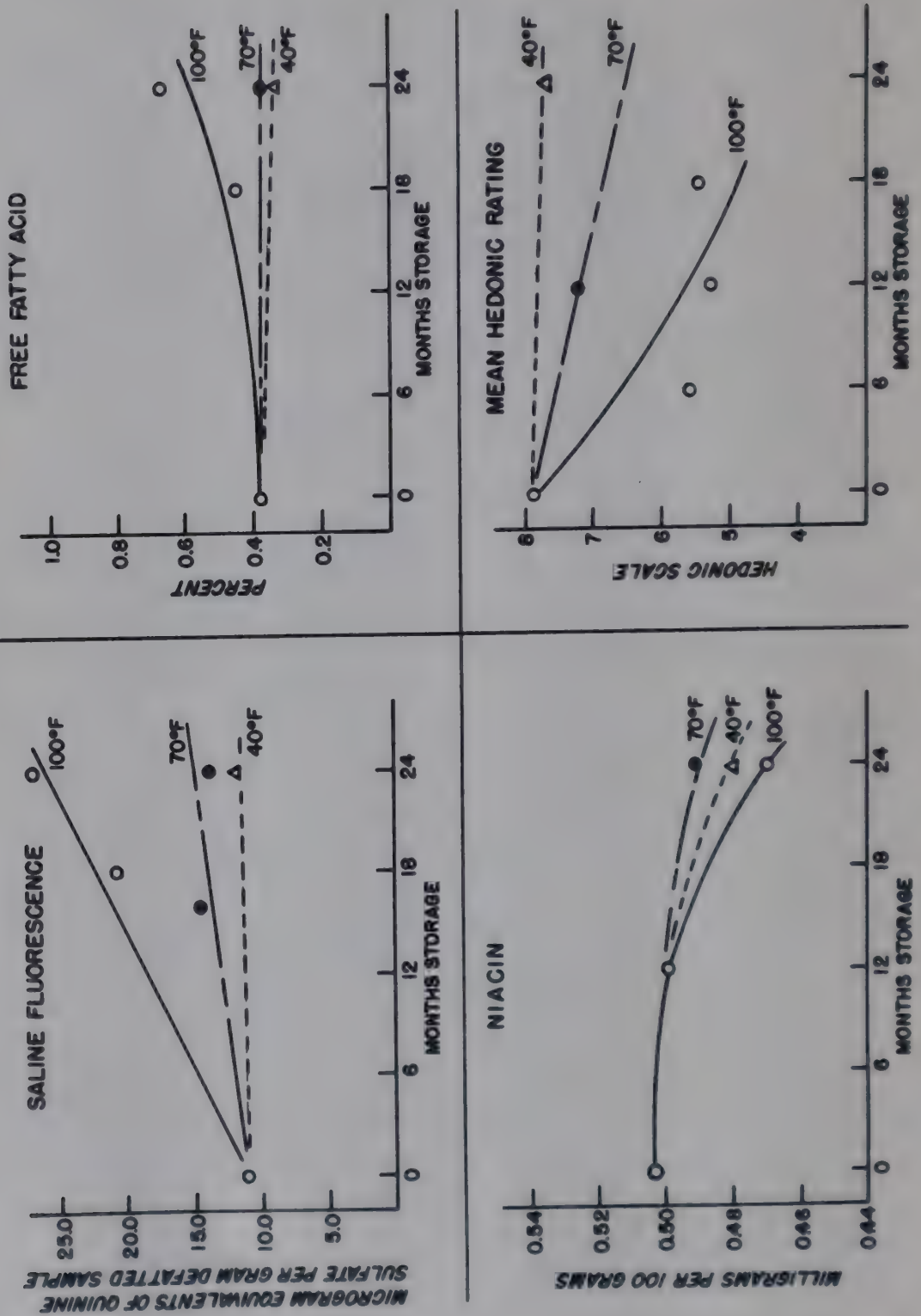


Figure 2.

CRACKERS

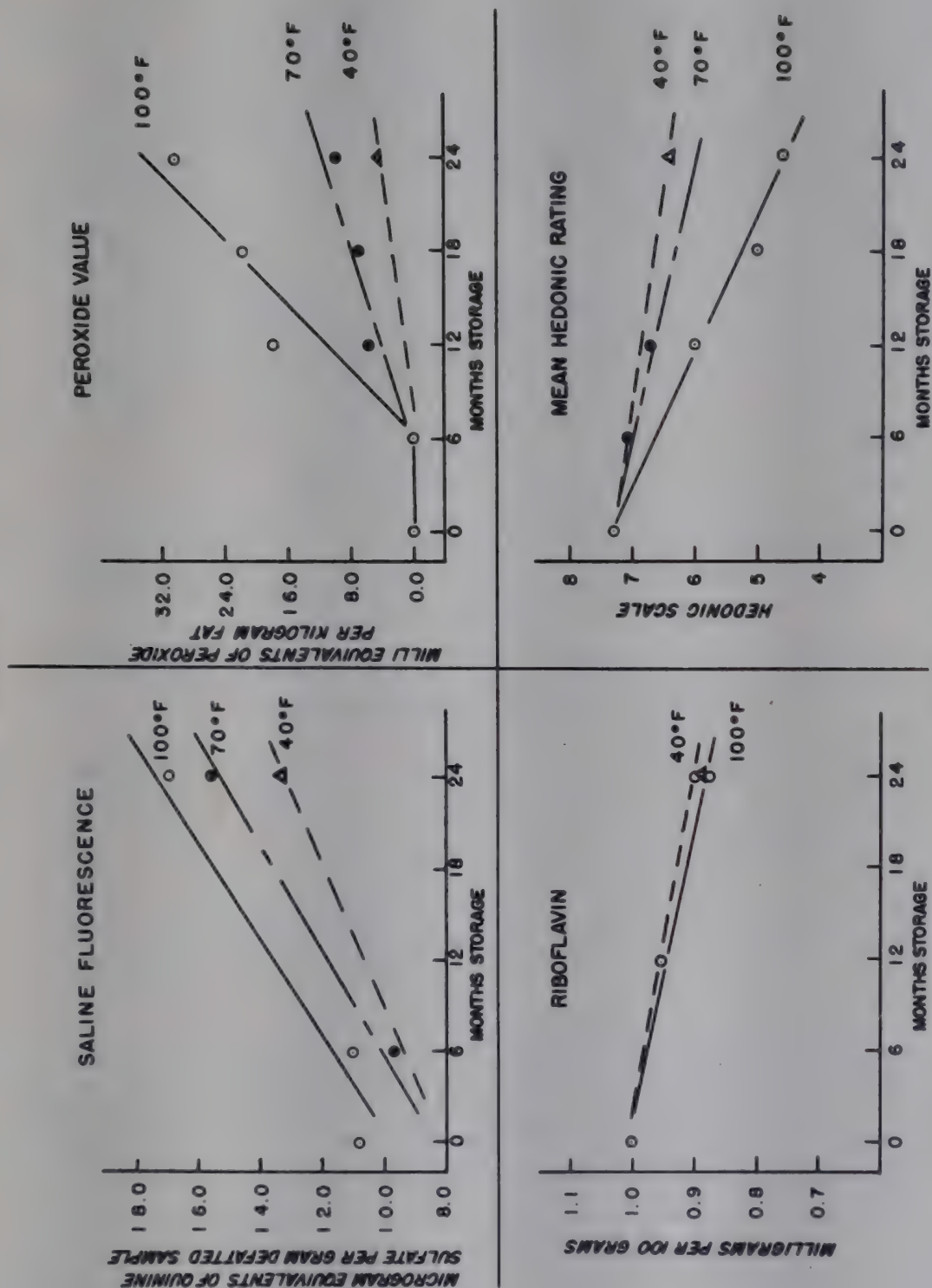


Figure 3.

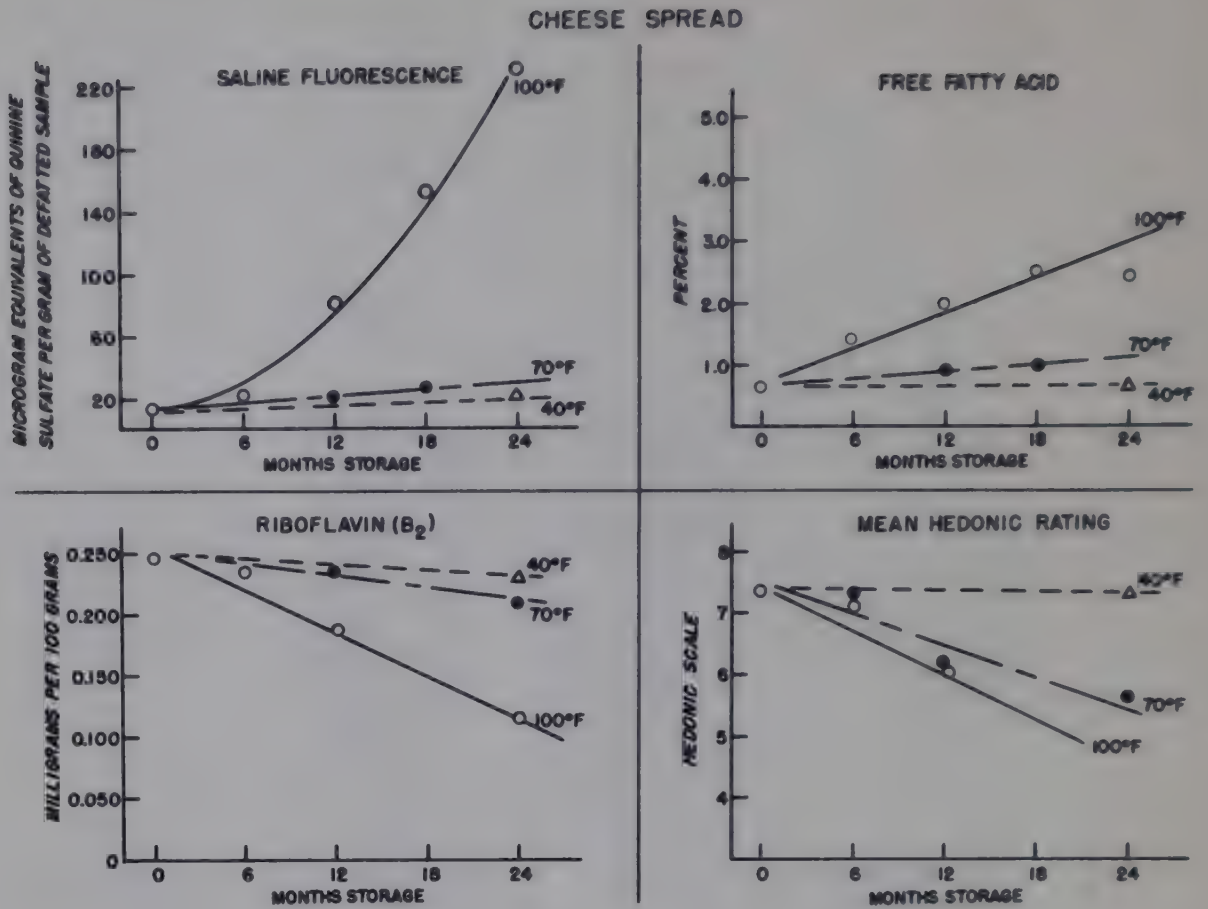


Figure 4

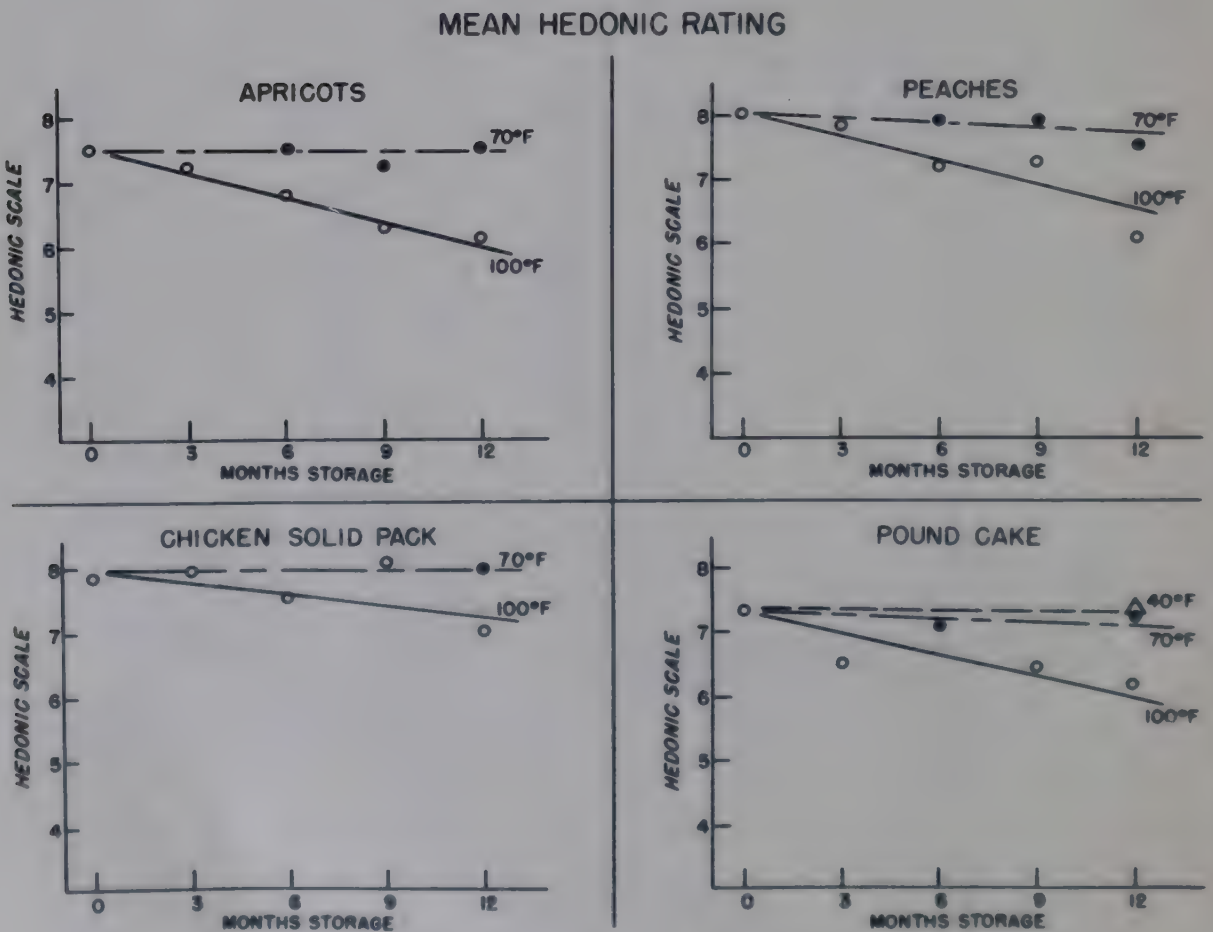


Figure 5

Figure 4 illustrates the effect of temperature upon some chemical changes and the acceptability of cheese spread. Formation of saline fluorescence, indicating a browning reaction, free-fatty-acid formation indicating fat hydrolysis, and riboflavin losses are considerably greater at 100° than at either 40° or 70° F. In this case, 40° F. storage held the cheese virtually unchanged for 2 years—the length of the study.

Studies have been under way for 12 months on the items shown in figure 5. There have been no changes at 70° F. for apricots, peaches, chicken, and pound cake. At 100° F., the decline in acceptability with time is obvious. It is predicted that apricots, peaches, and pound cake will no longer be suitable for use after approximately 18 months of storage at 100° F.

Figure 6 shows the results of storage for 18 months of the fudge bar and 24 months for the canned bread as measured by the consumer-type panel. Stability is again shown to be directly related to temperature and time.

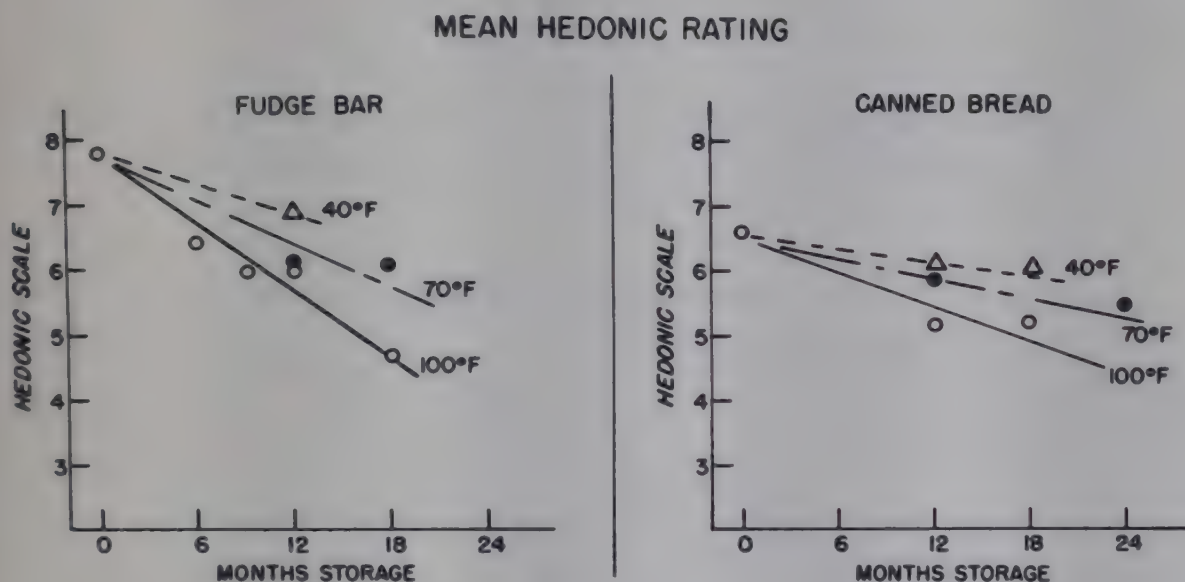


Figure 6

Figure 7 illustrates that the item beef and gravy is unusually stable so far as changes in acceptance ratings are concerned. We have just examined samples stored 3 years at 100° F. and found the cans badly swollen. There was considerable corrosion of the interior of the can and a gas analysis showed the presence of 40 percent hydrogen and 13 percent carbon dioxide. Indications are that this difficulty was due to chemical action on the can. The increase of free-fatty-acid value is indicative of fat hydrolysis.

Figure 8 giving data on canned white potatoes shows that thiamine is lost rapidly at 100°, slowly at 70°, and not at all at 40° F. There is evidence of a slight amount of browning reaction as shown by the increase in saline fluorescence and drop in dextrose. After approximately 12 to 15 months at 100° F., the product was no longer suitable for use.

BEEF AND GRAVY

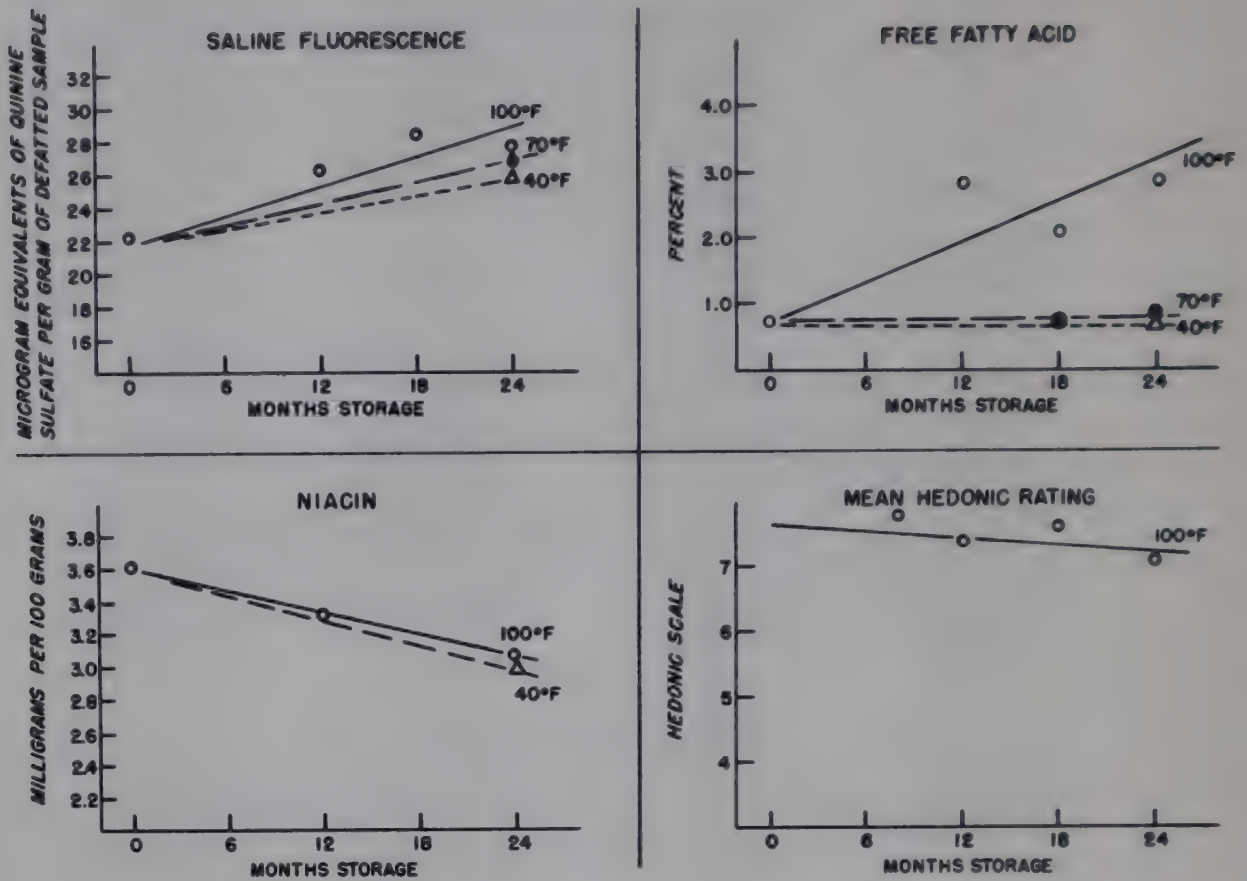


Figure 7

CANNED WHOLE WHITE POTATOES

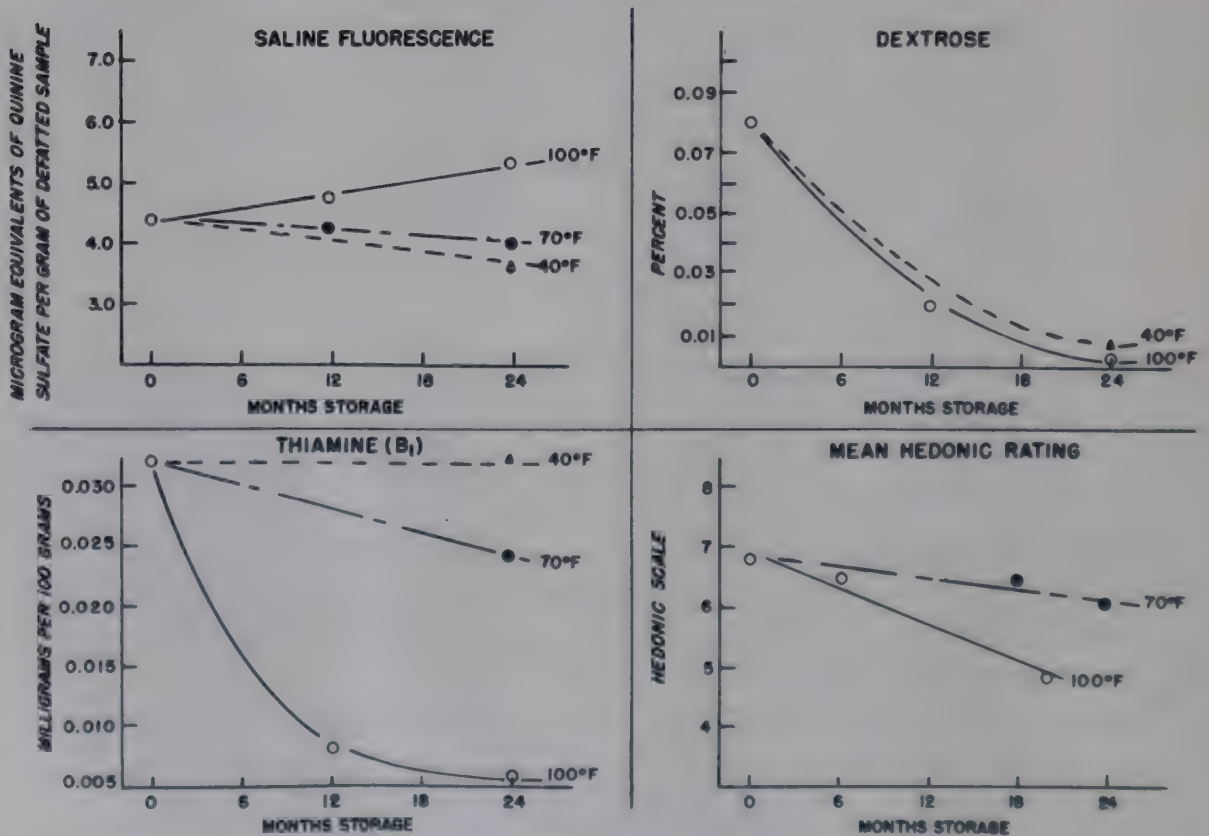


Figure 8

Figure 9 illustrates what happens to the starch-jelly candy upon storage. These particular candy discs were sealed in cans; therefore, could neither lose nor absorb moisture. The acceptance rating fell from approximately 7.8 to 6.0 in 18 months at 100° F. This candy was still considered edible, but the physical qualities of the candy

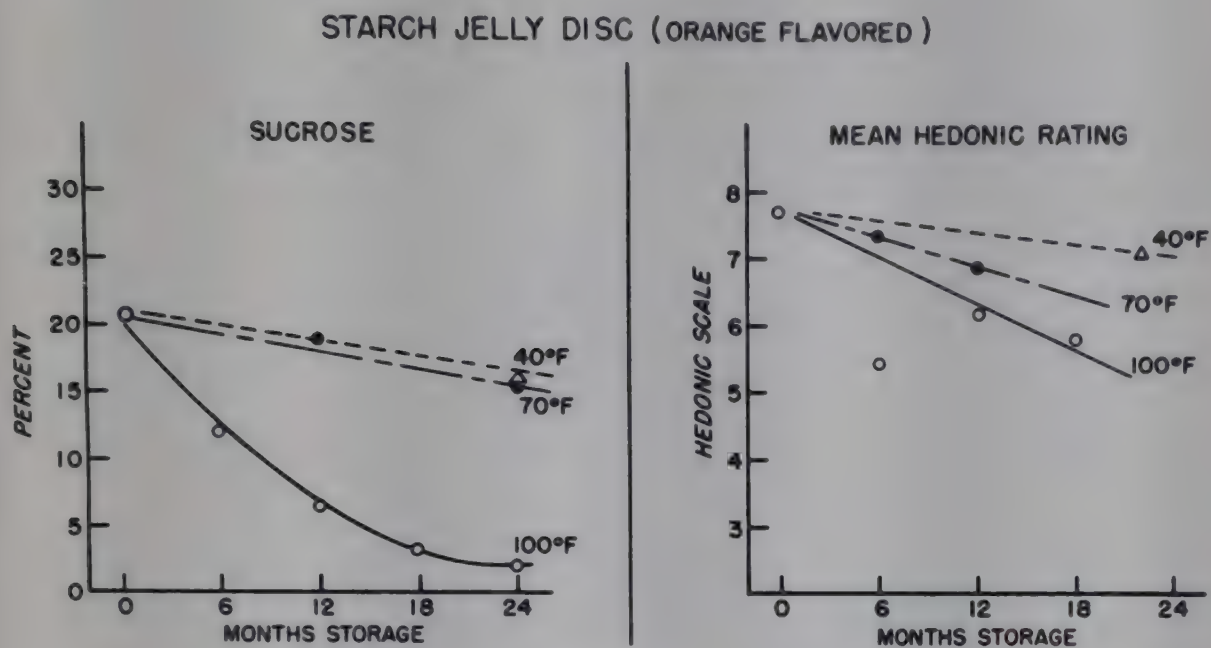


Figure 9

were not as desirable as at the beginning of the study. It had become more sticky and gummy. The most striking chemical change was that in the sucrose. This is caused by the acidity of the candy—the pH being approximately 4.5. Sucrose is inverted to glucose and fructose and it is thought that this may be responsible to some extent for the change in physical quality noted in these studies.

Turning next to sweetened dried milk, figure 10, we found a decrease in acceptability at both 70° and 100° F. The disappearance of lactose and increase in saline fluorescence is due to the browning reaction, while free-fatty-acid development would indicate some amount of fat hydrolysis. Oxidative changes which also occurred are not shown here. Any or all of these may be partially responsible for the decrease in acceptability.

Figure 11 indicates changes observed in canned sweet potatoes. While the acceptance rating changed significantly at 100° F. in 18 months time, very little change occurred at 70° F. Vitamin B₁, thiamine, was lost rapidly at 100° F.; but insignificant changes occurred at 40° and 70° F. Dextrose increase in saline fluorescence is not as serious in this product as in white potatoes, since we like a yellow color in sweet potatoes, but do not like our white potatoes to be dark.

MODIFIED SWEETENED DRIED MILK

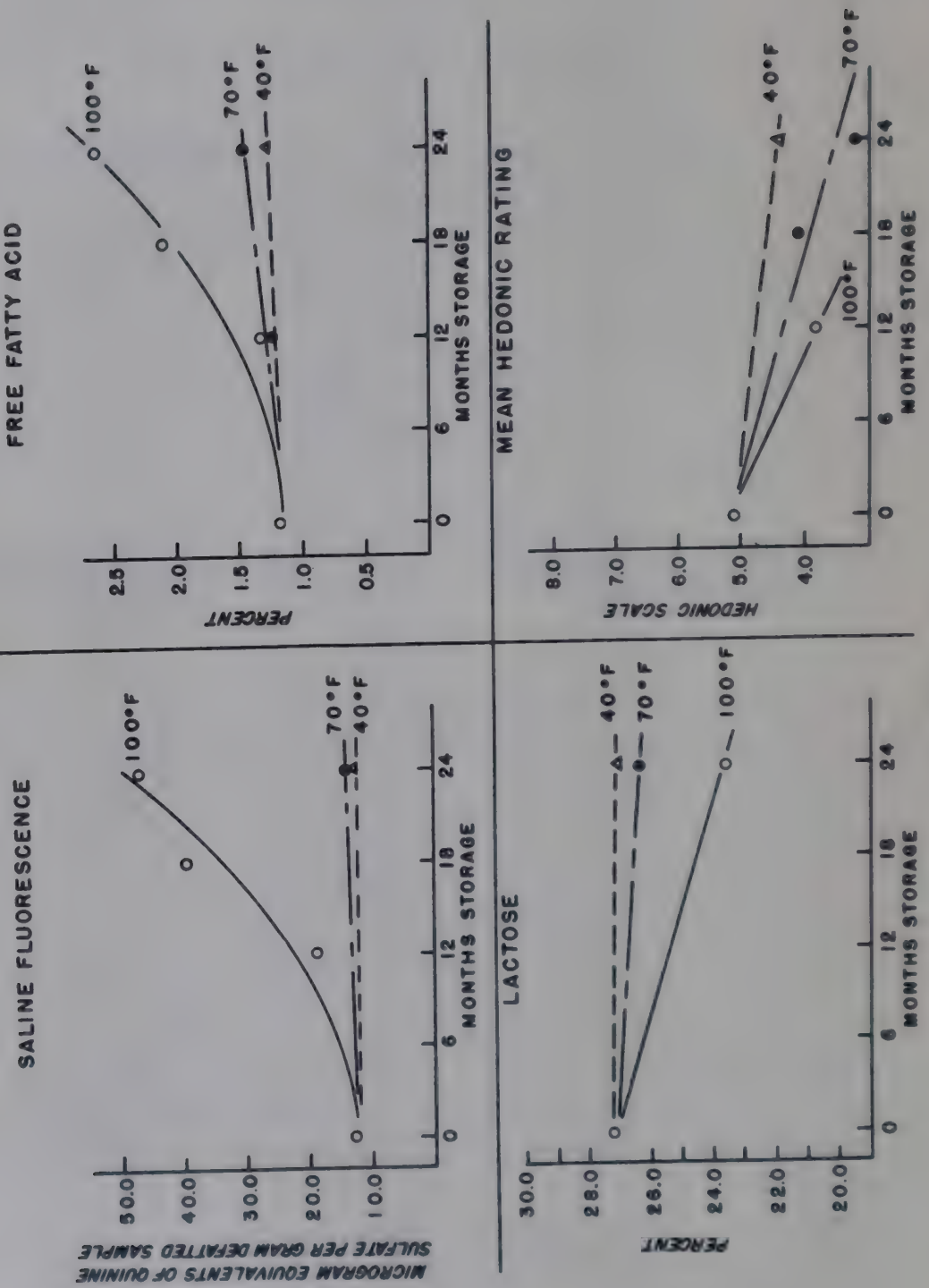


Figure 10

CANNED SWEET POTATOES

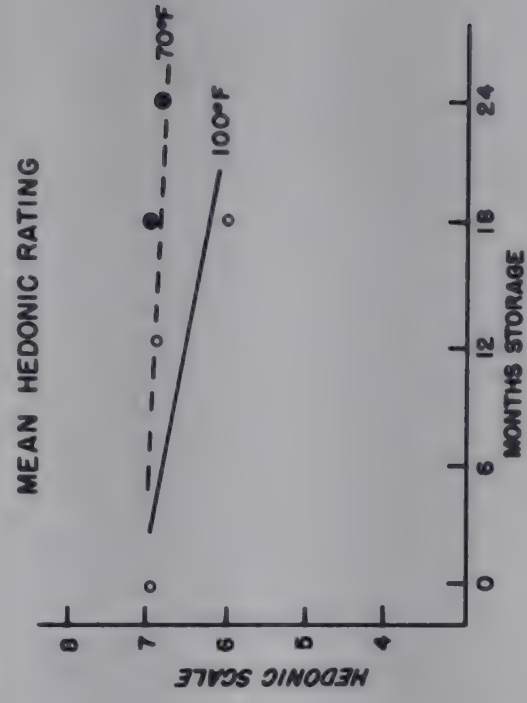
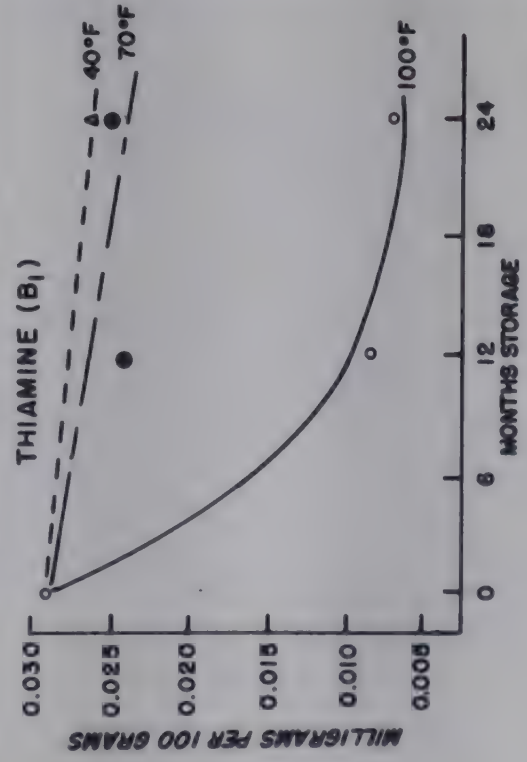
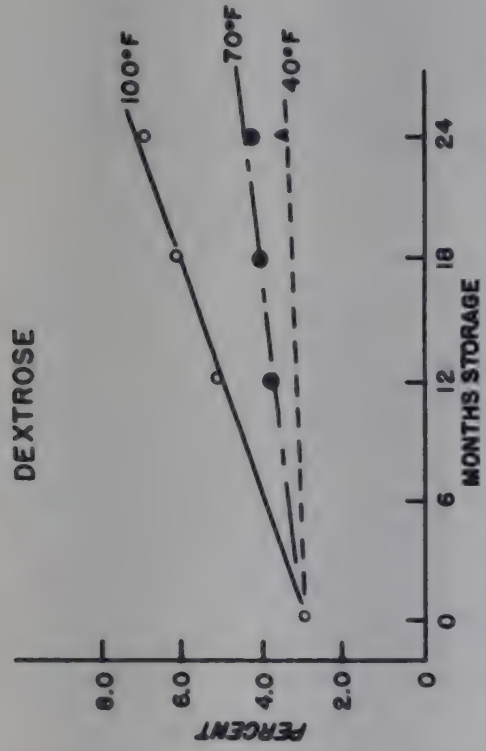
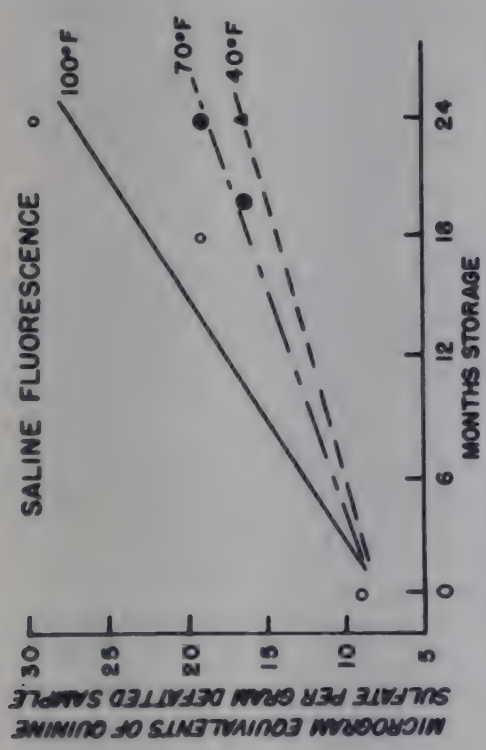


Figure 11

EVAPORATED MILK

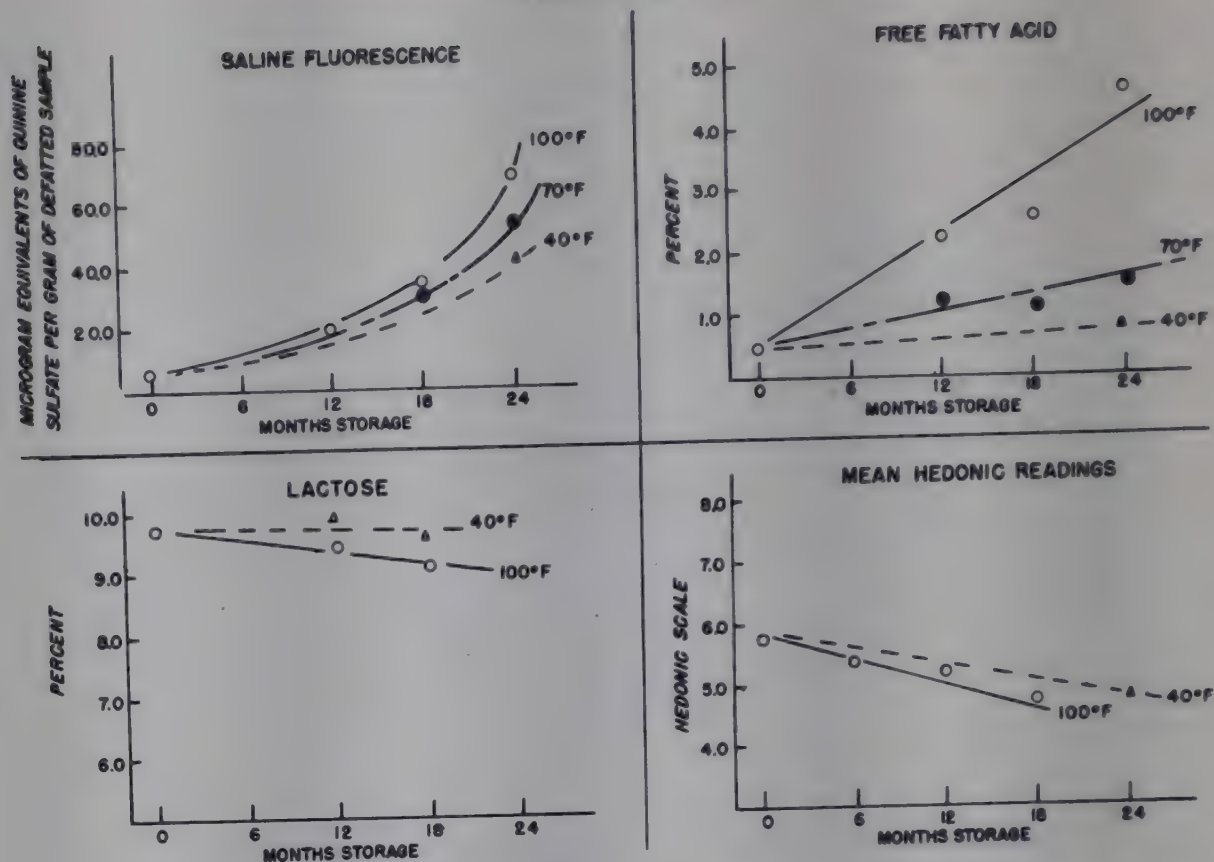


Figure 12

In figure 12 are shown changes occurring in evaporated milk. We have proof of fat hydrolysis as shown by free-fatty-acid development, browning as shown by the saline fluorescence values, and loss in acceptability. In addition to these changes, corrosion of the cans was severe and they became swollen during storage at 100° F. due to chemical action of the product or the deterioration of the product in the can.

Figure 13 illustrates some of the visual changes in food items during storage. This is the SA-2 Ration after storage for 2 years at 70° and 100° F. At the end of 1 year of storage at 70° and 100° F., there was no marked difference from prestorage in hedonic scale ratings.

At the end of 2 years at 70° F., none of the items had declined significantly from initial preference ratings; however, 2-year storage at 100° F. resulted in such extreme deterioration that the ration was completely unacceptable. There was excessive browning in the cereal bar, giving the item a distinctly mottled appearance. Soluble tea and coffee products had a black, tarry appearance. This was probably caused by absorption of moisture. The bouillon powder can be described as similar to charcoal. Gum pellets had become cream-to-tan in color and the chocolate bars were dry, almost powdery, with considerable evidence of "bloom." The fruit bars had a mottled black-and-brown appearance. It was quite evident that there had been a transfer of flavor from one item to another, and chemical analyses disclosed that moisture transfer had occurred.



Figure 13



Figure 14.

Figure 14 is of the Abandon Ship Food Packet. When stored for 3 months at 70°, 100°, and 140° F., the changes at 100° and 140° F. are clearly distinguishable. There was trouble due to inversion of sucrose, leakage of fats, and browning of the apricot fruit bar.

The data presented are typical of many other food products which we have in storage. It is obvious that storage at 40° F. has held changes of all types, in most items, to a negligible value. At 70° F., the deteriorative changes take place at a rate which varies with the food item. Many items are still usable after 2 years storage at this temperature, but lack their initial high quality. Between 70° and 100° F., pronounced deterioration takes place, resulting in the majority of products becoming unfit for use within 6 to 18 months of storage at 100° F.

It has become obvious that the old rule of thumb that 6 months of storage at 100° F. is equivalent to 2 years at 70° F. is not true in most food items. In general, ration items keep at least 3 times longer at 70° than at 100° F., and indications are that the majority of ration items would keep in good condition for a minimum of 5 years at 40° F. We are not in a position to state a relationship between keeping time at various temperatures which would apply to all food items, however.

Although constant improvement has been made in food stability, high quality at the time of feeding and avoidance of waste can only be achieved, when storage is necessary, by storage at cool temperatures.

CHAIRMAN TRESSLER:

Dr. J. G. Woodroof, our next speaker, is head of the food technology work at the Georgia Experiment Station. He has been a leader in studies on the production and storage of frozen foods for 30 years or more; and later, in the investigations on canned foods in both production and storage. He has done practically all the pioneering work in the storage of peanuts, pecans, and other nuts, and is also a leader in the storage of candies and confections.

Dr. Woodroof will describe what he has learned in the past 21½ years in regard to the storage of subsistence.

Ration Storage Requirements

J. G. WOODROOF

Department of Food Technology, Georgia Agricultural Experiment Station

What I say will be a continuation of the reports that Dr. Mitchell and Dr. Mrak made, and it is amazing how closely the results fit, even though the work was done under an entirely independent setup with respect to refrigeration rooms, personnel, and method of analysis.

In 1951, a 2-year research project was undertaken between the Quartermaster Food and Container Institute of Chicago, and the Georgia Experiment Station to determine the effects of storing certain military rations at widely different temperatures. Specific objectives were to determine: (a) the stability of flavors, colors, and texture of the edible components, (b) the interchange of moisture or flavors between components, and (c) the adequacy of the packages to protect the original qualities of the respective components.

In a 2-year experiment begun in 1951, a total of 1,225 B-2 units of C Rations and 2,210 of 5-in-1 Ration Dry Packs were stored at the Georgia Experiment Station at five temperatures—minus 10°; 70°; 100° F.; 70° alternating with 100° F.; and minus 10° alternating with 100° F. The latter were cycled at 2-week intervals. The storage conditions were to simulate: (a) very cold climate or “freezer” storage, (b) common storage in middle United States, (c) storage in a hot climate, and (d) storage under widely variable temperature conditions. The products were examined initially and after 3, 6, 9, 12, 18, and 24 months in storage. About 100,000 visual examinations, 25,000 moisture determinations, and 3,000 sensory evaluations of components were made.

In a 5-year experiment begun in 1953, approximately 35 canned and 15 flexible packaged products from Quartermaster operational rations were selected for storage tests at the Georgia Experiment Station to determine the effect of relative humidities and types of containers on grades, drained weights, sensory values, vitamins, rancidity, and other measurable qualities.

Approximately 50 representative products are included in this experiment. Among them are: (a) meat and fish products including beef and vegetables, tuna and noodles with cheese, salmon, ground meat and spaghetti, ham chunks, pork and gravy, pork steaks, beef steaks, sausage patties, bacon, chili con carne, and meat food product bars; (b) cereal and baked products including bread, cake, cookies, steamed pudding, crackers, spaghetti, and cereal bars; (c) dairy, oil and fat products including dry whole milk, nonfat milk solids, oleo-margarine, dry ice cream mix, and coffee-type cream; (d) fruit and vegetable products including whole-grain corn, fruit cocktail, plums, peaches, tomatoes, and white potatoes; and (e) general products including candy, sweet chocolate, coffee, cocoa mix, and B-1 and B-2 units for combat rations.

All products are stored at 100° F. and 50 percent r. h., 70° and 50 percent r. h., 47° and 75 percent r. h., 32° and 75 percent r. h. (relative humidity), 0° and equilibrium, and minus 20° F. and equilibrium. Products in flexible packages are also stored at 100° F. and 90 percent r. h., and at 70° F. and 90 percent r. h. All products are alternated after 12 and 24 months storage at 47° and 32° to 100° F. and 90 percent r. h.

Twelve types of candy bars in Dry Packs (table 1) and 4 types of candy discs in B-2 units (table 2) were used; all other components of the respective ration units were the same. The use of humectants and antioxidants further varied the formulas for candies, but changes due to these additives generally have been of minor importance compared with the effects of storage temperatures. The storage conditions in which the temperatures were cycled produced practically the same effect as continuous storage at 100° F., except that changes occurred at a slightly reduced rate.

Some of the more important findings resulting from the completed 2-year study are detailed below:

Components varied in response to storage temperature. Five components of B-2 units and six components of Dry Packs were affected directly by storage temperatures, while all others were affected indirectly by virtue of being in proximity to those which deteriorated as storage temperature increased (table 3).

Table 1. The moisture content of seven components of five-in-one rations as effected by three storage temperatures and twelve types of candy

Storage Temperature °F.	Components							
	Candy (Percent)	Cereal Bar (Percent)	Choco- late Bar (Percent)	Cocoa Powder (Percent)	Cigar- ettes (Percent)	Dry Pack Carton (Percent)	Towels (Percent)	Toilet Tissue (Percent)
Before Storage								
	3.93	1.25	3.07	11.30	7.77	6.47	6.76	
After Storage for 18 Months with:								
<i>Glazed Peanut Brittle Bars (3.19%)*</i>								
-10.....	3.16	3.05	1.19	3.27	9.89	6.87	6.14	6.30
70.....	3.81	3.27	1.24	3.13	8.72	6.56	5.70	6.11
100.....	4.11	3.76	1.21	3.14	8.31	6.73	5.69	6.06
<i>Chocolate-coated Peanuts (2.71%)*</i>								
-10.....	2.23	3.05	1.17	3.21	10.17	7.01	5.93	6.00
70.....	2.18	3.30	1.27	3.13	9.19	7.08	5.61	6.05
100.....	2.83	3.96	1.52	3.09	8.95	6.63	5.42	5.95
<i>"Cocoa-type" Coated Peanut Butter Spun Bars (3.21%)*</i>								
-10.....	2.94	3.12	1.29	3.21	10.63	6.92	6.14	6.61
70.....	3.89	3.29	1.35	3.10	9.30	6.64	5.46	6.83
100.....	4.81	4.07	1.34	3.04	9.32	6.55	5.36	6.09
<i>Chewy Carmels (8.01%)*</i>								
-10.....	6.70	3.55	1.15	3.28	10.33	6.97	5.83	6.21
70.....	7.87	3.64	1.25	3.22	9.53	6.71	5.77	6.05
100.....	8.64	4.13	1.49	3.35	9.55	6.58	5.51	6.14
<i>Grained Caramels (8.30%)*</i>								
-10.....	9.29	3.54	1.24	3.30	10.89	6.89	5.79	6.08
70.....	8.50	3.99	1.32	3.41	10.00	7.00	5.76	6.30
100.....	8.67	4.44	1.56	3.63	9.47	6.75	5.62	6.21
<i>Candy Corn (5.46%)*</i>								
-10.....	5.66	3.36	1.34	3.41	10.40	6.82	5.72	6.05
70.....	4.61	3.90	1.18	3.43	9.81	7.05	6.00	6.35
100.....	4.03	4.39	1.34	3.62	9.54	6.60	5.33	6.23
<i>"Cocoa-type" Coated Coconut Bars (9.15%)*</i>								
-10.....	9.11	3.27	1.23	3.33	10.66	6.75	5.94	6.27
70.....	7.32	4.46	1.37	3.42	10.05	7.01	5.86	6.41
100.....	6.75	4.57	1.31	3.89	10.00	6.87	5.68	6.48
<i>"Cocoa-type" Coated Fudge Bars (8.75%)*</i>								
-10.....	10.79	3.12	1.24	3.28	10.02	6.97	5.96	6.26
70.....	4.61	4.02	1.31	3.47	9.79	6.94	5.72	6.50
100.....	5.60	4.36	1.38	4.19	9.98	6.85	5.79	6.29
<i>"Cocoa-type" Coated Peanut Roll Bars (Center 8.45%)* (Peanuts 5.48%)*</i>								
-10:								
Center.....	8.18	2.85	1.22	3.25	10.23	6.75	5.82	6.46
Peanuts.....	5.02							
70:								
Center.....	7.08	3.69	1.33	3.34	9.74	6.87	5.70	6.45
Peanuts.....	4.42							
100:								
Center.....	6.71	4.23	1.41	3.43	9.77	6.68	5.53	6.37
Peanuts.....	4.17							
<i>"Cocoa-type" Coated Carmel Nougat Bars (9.01%)*</i>								
-10.....	10.63	3.28	1.20	3.23	9.73	6.87	5.93	6.38
70.....	9.13	3.59	1.39	3.14	9.71	6.87	5.62	6.44
100.....	8.87	4.34	1.35	3.36	9.70	6.93	5.54	6.50
<i>Starch-jelly Bars with Fruit (12.54%)*</i>								
-10.....	10.44	3.29	1.20	3.31	10.82	6.89	6.13	6.63
70.....	9.63	4.07	1.49	3.41	10.68	6.90	5.69	6.66
100.....	9.85	4.51	1.54	3.74	9.93	6.52	5.57	6.51
<i>Starch-jelly Bars without Fruit (13.76%)*</i>								
-10.....	13.47	3.86	1.27	3.62	11.35	7.25	6.02	6.84
70.....	11.37	4.77	1.57	3.96	12.16	7.37	6.08	6.98
100.....	10.16	5.09	1.72	5.46	10.62	6.96	5.85	7.00

*Moisture content when placed in storage.

Table 2.—The moisture content of seven components of B-2 units of combat rations effected by three storage temperatures and four types of candy

Storage Temperature °F.	Components							
	Candy (Per- cent)	Cookies		Crackers (Per- cent)	Coffee (Per- cent)	Milk (Per- cent)	Paper	
		Cake Portion (Per- cent)	Cream Center (Per- cent)				Divid- ers (Per- cent)	Liners (Per- cent)
Before Storage								
-----	-----	6.54	1.10	7.27	3.54	3.11	9.14	10.07
After Storage for 18 Months with:								
Coconut Cream (9.40%)								
-10-----	7.91	4.44	1.02	5.53	2.13	2.89	6.69	7.60
70-----	6.28	4.78	.95	6.56	3.20	3.35	6.70	7.78
100-----	5.40	4.61	.98	7.19	5.28	4.08	6.40	7.42
Caramel Nougat (8.88%)								
-10-----	7.00	4.47	1.02	5.97	1.98	3.04	6.59	7.06
70-----	7.00	4.75	.95	6.33	3.72	3.41	6.59	7.88
100-----	6.60	4.64	1.00	6.95	5.12	3.72	6.31	7.62
Starch Jelly without Fruit (17.11%)								
-10-----	14.46	5.45	1.15	6.72	1.91	2.97	7.14	8.41
70-----	12.36	7.10	2.04	9.44	4.03	3.83	7.60	9.11
100-----	11.81	6.75	2.39	9.27	3.67	3.92	7.41	8.68
Starch Jelly with Fruit (14.81%)								
-10-----	13.96	5.29	1.03	6.61	3.09	3.09	6.95	8.10
70-----	11.40	5.60	1.17	8.08	7.44	3.61	7.22	8.50
100-----	13.39	4.67	1.25	7.93	9.15	3.88	6.87	7.92

Table 3. Components of two units of operational rations which retained quality longer under refrigeration, and items which were indirectly affected by storage temperatures

Refrigeration	
Directly Beneficial	Indirectly Beneficial*
5-in-1 Rations, Dry Packs	
5 candy, bars	5 matches, books
5 cereal, bars	1 salt, envelope
10 chocolate, bars	3 sugar, envelopes
5 cocoa powder, envelopes	1 toilet tissue, envelope
3 chewing gum, cartons	1 non-woven fabric towels, pkg.
5 cigarettes, packs	
Combat Rations, B-2 Units	
1 candy, disc	1 sugar, packet
1 cookie, sandwich	
4 crackers	
1 coffee, soluble, packet	
1 milk, powdered, packet	

*Stored at 100° F., these components were indirectly damaged by migrating fats from chocolate bars, cereal bars, and candy.

The lowest temperatures were most effective in preventing deterioration. Changes which occurred in rations during storage included loss of fresh aroma and flavor, bleaching or darkening of color, gain or loss of moisture, staling or rancidity of fats, and changes in texture (as with cereal bars, chocolate bars, and candies).

It was found that cereal bars reached the borderline of sensory acceptability (scored 4.5) when stored at 100° F. for 5 months, when stored at 70° F. for 14 months, and when stored at minus 10° F. (estimated) for 40 months. The corresponding periods for chocolate bars were 5, 12, and 30 months; for cocoa beverage powder they were 3, 9, and 18 months; for crackers they were 12, 28, and 68 months; and for sandwich cookies they were 9, 18, and 48 months. In general, edible components remained acceptable about one-third as long at 100° as at 70° F., about two and one-half times as long at minus 10° as at 70° F., and about 6 times longer at minus 10° than at 100° F. (See fig. 1.)

Migration of fats was prevented by refrigeration. Migration of fats, resulting in accelerated staling and rancidity in certain components, was the most serious storage problem and was directly related to temperatures. When cereal bars, sweet chocolate bars, and high-fat-content candies were stored at temperatures sufficiently high to melt the fats (85° to 95° F.), they lost original appearance, aroma, and flavor rapidly. Not only did the individual components become greasy, but usually the wrapper and adjacent components were grease-stained.

Stored at 70° F. or lower, there was no migration of fats over a 2-year period. Stored at 100° F., migrating fats caused serious staining and damage of other components and packaging materials within a few days, and rendered the products unacceptable or unusable, due to rancidity, within 3 to 12 months. There were drastic chemical and physical changes as well as lowering of sensory values within 6 months. As ration units were opened, there was a very disagreeable rancid odor, and the items were unappetizing in appearance.

Interchange of moisture and corrosion of interiors of cans were reduced with storage temperatures. Interchange of moisture was least at minus 10° F. and greatest at 100° F. Candies varied in moisture from less than 3 percent in pan-coated peanuts to more than 17 percent in starch jelly. The moisture content of low moisture candies increased and that of high moisture candies decreased in storage. Other components gained or lost moisture proportional to the moisture content of the candies and the storage temperature. Corrosion of the inside of tinned cans (fig. 2) of B-2 units was related primarily with moisture content of the components and secondarily with storage temperature. In these experiments, high-moisture-content candies were the chief source of moisture for corrosion of cans. Stored at minus

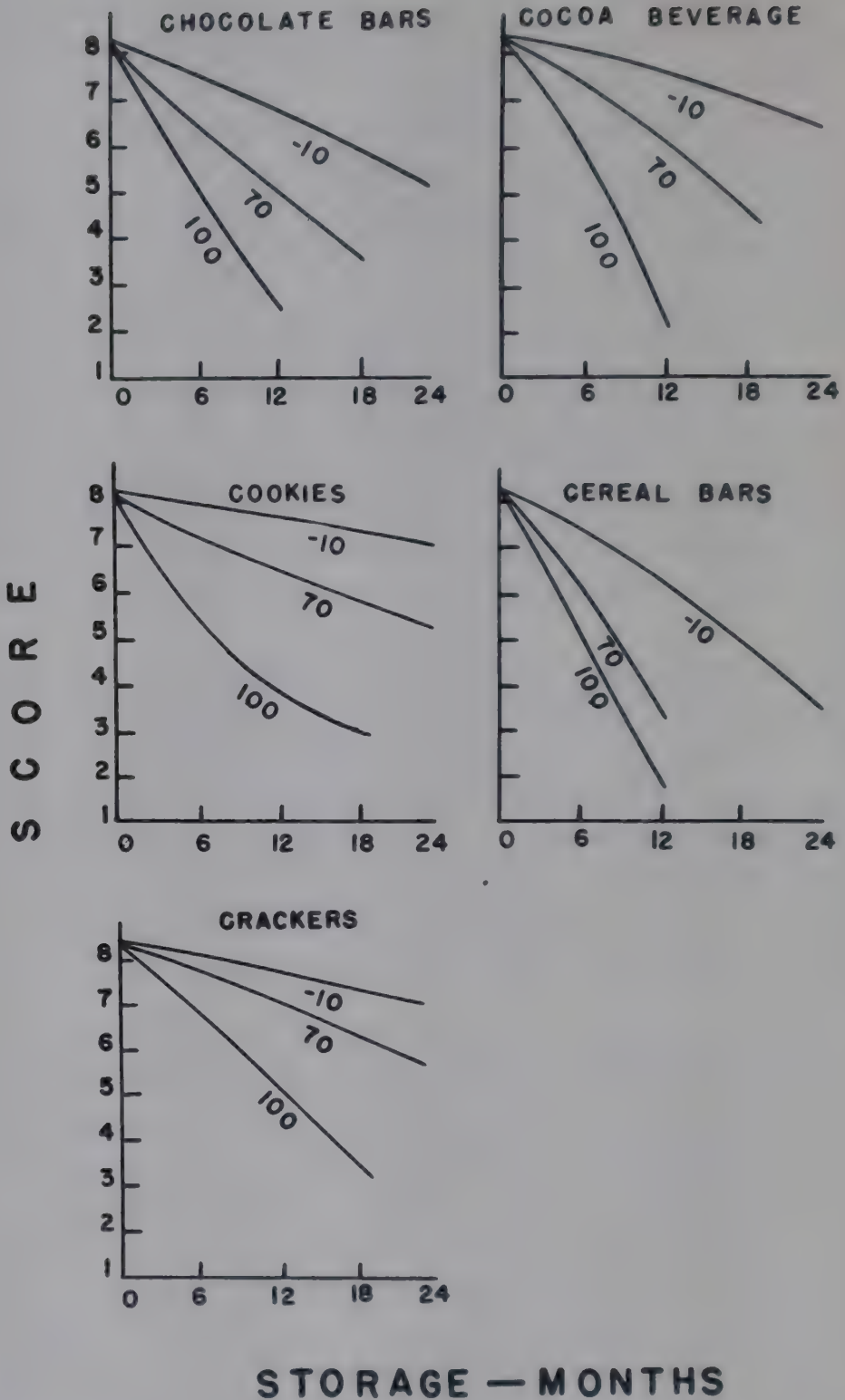


Figure 1.

10° F. for 24 months, the interiors of all tinned cans were free from corrosion, at 70° only cans containing starch-jelly candies corroded, while at 100° F. all cans corroded on the inside. Corrosion was worse on the interior of the tops (figs. 3 and 4), and was first noticed after 9 months storage.

Insect injury was prevented by refrigerated storage. Infestation by the confused flour beetle (*Tribolium confusum*) occurred occasionally in rations stored at 70° and 100° F., but not at minus 10° F. Components most commonly attacked were: cereal bar, peanut candies,

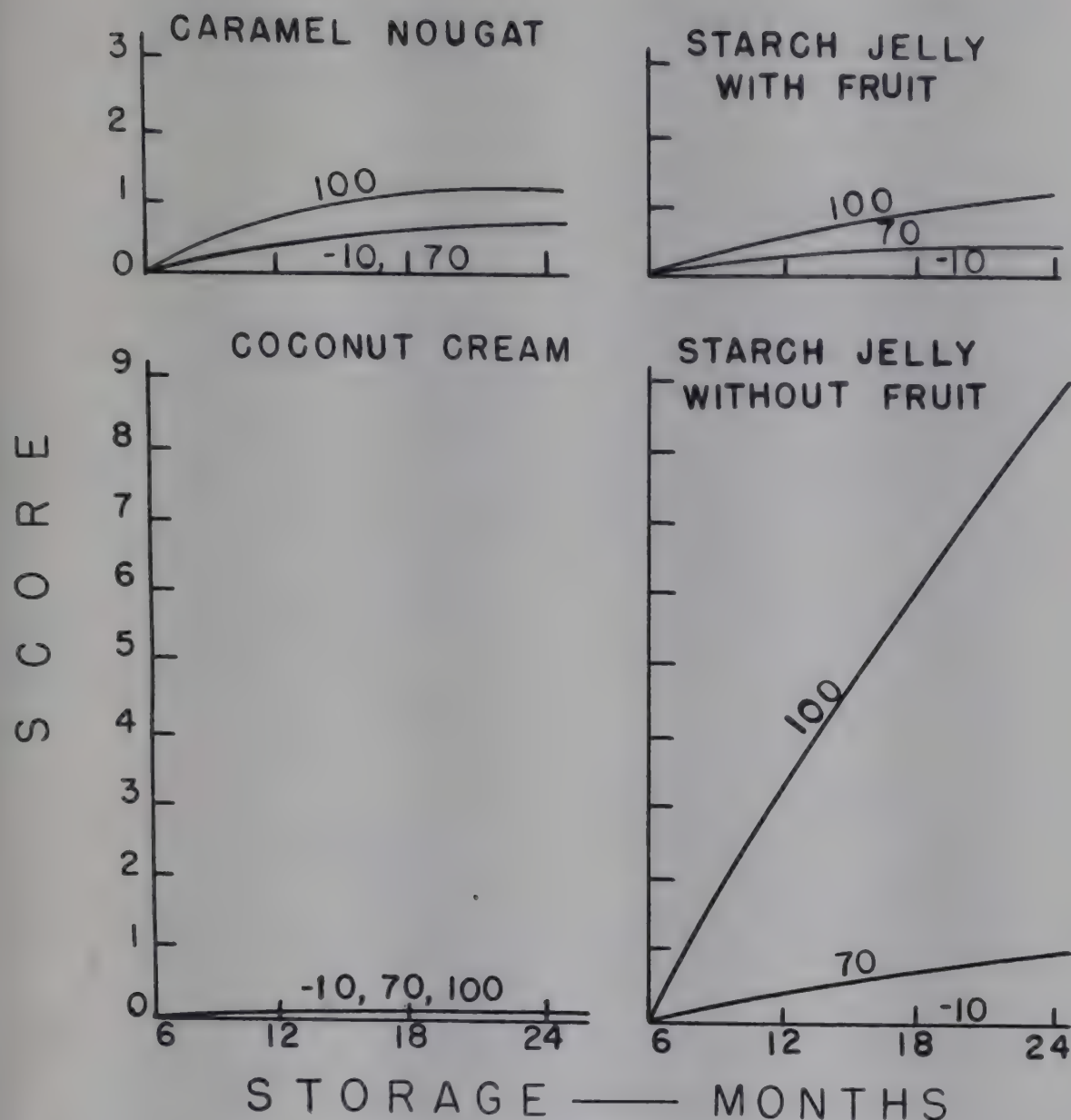


Figure 2.

chocolate bars, and chocolate-coated candies. (See figure 5.) Other experiments showed that this and other pantry pests were inactive at temperatures below 48° F.

Storage at minus 10° F. did not adversely affect Dry Packs and B-2 units. During the course of this 2-year study 432 5-in-1 Rations and 240 B-2 units were removed from minus 10° storage to room temperature (72° and 60 percent r. h.) and opened for examination about 18 hours later. It was found that about 24 were required for the temperature in individual cases of 8 Dry Packs (8¾" x 13¼" x 22") to equalize.

Condensation appeared on the outside of the cases immediately upon removal from the lower temperature, but in all instances it evaporated within 6 hours without injury to the contents. From a detailed examination of the external and internal condition of the packages and components, no general adverse effects were found from storing these rations at minus 10° F. Cracking of the cellophane wrappers and peanut butter spun candy bars was the only damage noticed.

Also, during the course of these studies 432 5-in-1 Rations and 240 B-2 units were alternated, at 2-week intervals, from minus 10° to 100° F. A portion of these was examined every 3 months, but some were transferred as many as 48 times during the 2-year study. All of the adverse effects of storage of these rations were of such a nature as to be attributed to the higher temperature. Under alternating storage temperature conditions refrigeration was of little or no advantage, but there was no damage caused by it. No cans of fruits, vegetables, or meats were included in the first storage test, but it is known that freezing adversely affects the texture of many products of high moisture con-

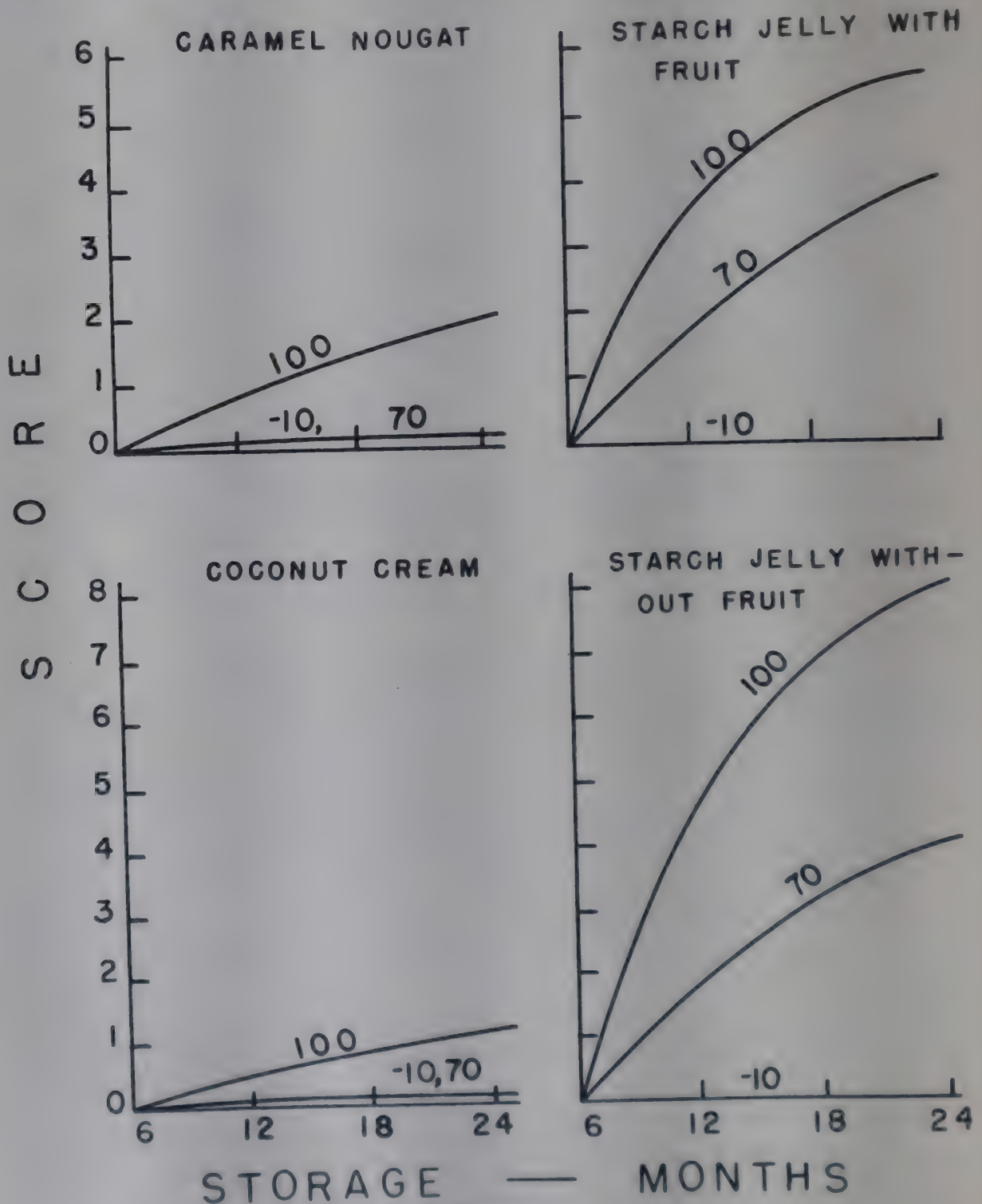


Figure 3.

1. Starch jelly without fruit, lime-flavored, 5 percent sorbitol, corrosion rating—2.
2. Starch jelly with fruit, 8 percent sorbitol, corrosion rating—5.
3. Starch jelly with fruit, 5 percent sorbitol, corrosion rating—7.
4. Starch jelly without fruit, orange-flavored, 3 percent sorbitol, corrosion rating—8.

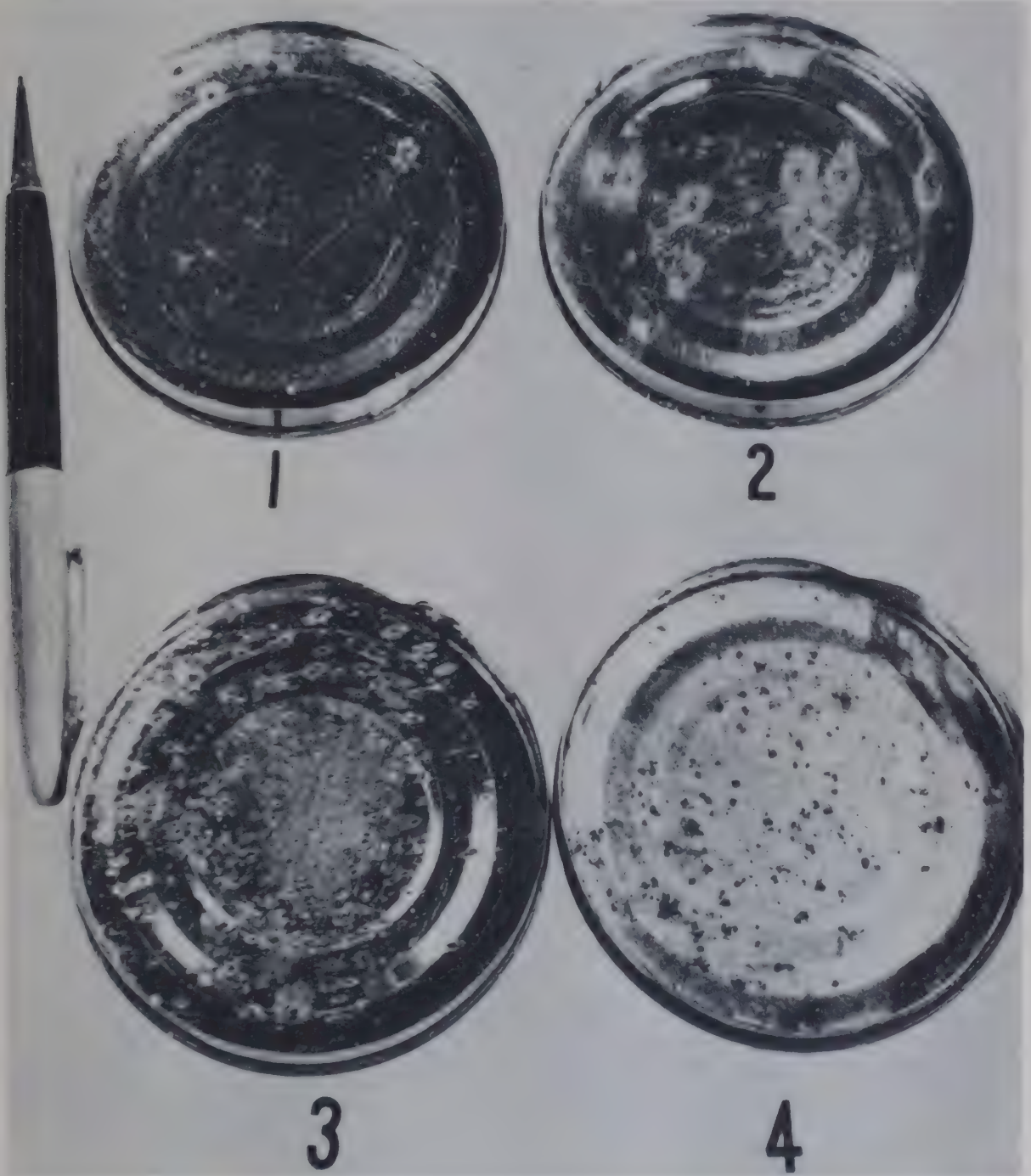


Figure 4. The relative amount of corrosion on the lids of combat rations produced by four types of candies.

tent. It is recommended that the lowest temperature, short of freezing, be used for storing canned fruits, vegetables, and certain meats.

All components lost quality rapidly at 100° F. storage. Changes in individual components of 5-in-1 Rations were as noted below:

Cereal bars became dark-colored, stale and rancid; the wrappers were greasy. (fig. 6)

Solid chocolate bars "grayed," became soft and porous due to loss of fat; the wrappers were very greasy. (fig. 6)

Cocoa beverage powder became heavy, lumpy, dark and rancid; the packets were grease-stained. (figs. 7 and 8)

Cigarettes became dry and strong; the wrappers and tobacco darkened; printing on the pack wrapper faded and the inside paper was stained.

Chewing gum and cartons were often grease-stained by fat migrating from other products; the gum often had a disagreeable, "hot" flavor.

Salt often spilled because glue seals of the paper envelopes failed, with the salt adhering to the grease-stained envelopes.

Matches, sugar, towels, and toilet tissue were seriously stained by fat from cereal bars, chocolate bars, and candy.

These changes occurred in individual components of B-2 units of C

Rations:

Cookie cream centers were dark and rancid.

Crackers became increasingly rancid and were very soggy in rations with starch-jelly candies.

Soluble coffee acetate-foil packets developed pinholes, which permitted entrance of moisture, causing severe caking.



Figure 5.



Figure 6.



Figure 7. On the left are "cocoa-type" pan-coated peanuts and the cartons soaked with fat migrated from the peanuts, in storage for nine months at 100° F. On the right are cocoa beverage powder and the area of the envelopes soaked with fat outlined in ink.



Figure 8. When stored at 100° F. for 12 months peanut bars darkened and became rancid; caramel nougat bars became soft, sticky, and runny; and cocoa beverage powder leaked fat which stained the packets.

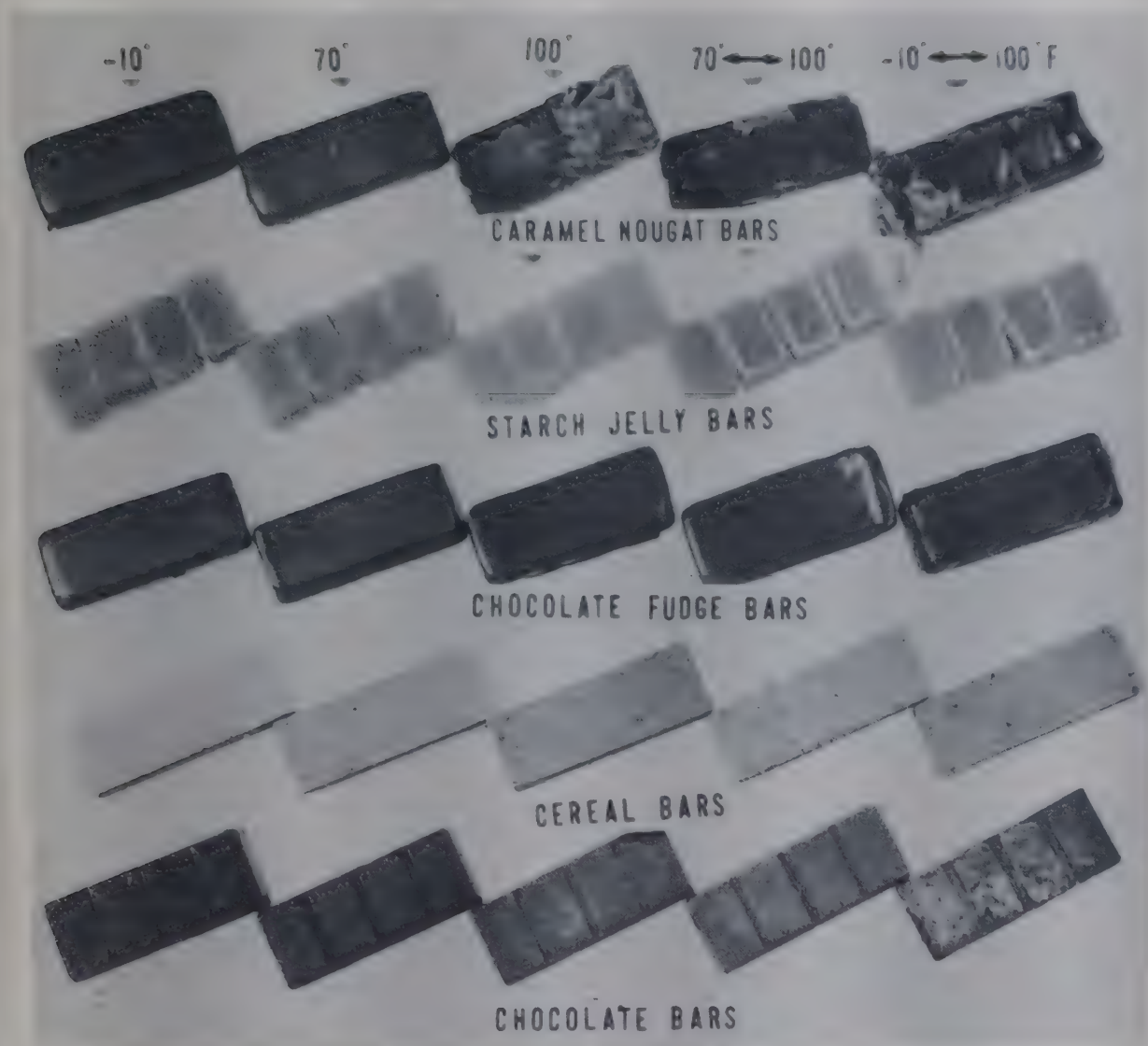


Figure 9. The appearance of five components of 5-in-1 rations after storage at five temperatures for six months: At 100° F. caramel nougat bars cracked and leaked; starch-jelly bars "cheesed" and crystallized; chocolate fudge bars cracked and the centers leaked; cereal bars darkened and became rancid; chocolate bars bloomed, and became dry and crumbly.

Dried milk packets of acetate-foil developed pinholes permitting caking and severe rancidity.

Sugar in heat-sealed paper envelopes spilled into the ration and was often stained by melted wax from the paper.

Candies in Dry Packs behaved as follows (figs. 8, 9, and 10) :

Peanut brittle crystallized and darkened; the nuts became soggy and rancid.

Pan-coated peanuts became soggy and the coating rancid. (fig. 7)

Peanut butter spun candy became tough, chewy, dark-colored, and rancid.

Chewy caramels grained, became sticky, dark-colored, and strongly flavored.

Grained caramels developed a dark color and strong flavor.

Coconut cream centers were very dark with "soapy" flavor.

Candy corn became dry, tough, and faded.



Figure 10. Note change in color and crystallization of lemon (top), lime (middle), and fruit (bottom) starch-jelly bars, stored at four temperatures for nine months.

Chocolate fudge became dry, hard, rancid with tobacco-like flavor. Caramel nougat leaked caramel and became "grayed," rancid. Peanut rolls, centers became very dry and hard, nuts became stale, and the coating reddened.

Starch jelly with fruit became very dark, sticky, and flavor strong. Starch jelly without fruit became "cheesy," faded and with terpene flavor.

CHAIRMAN TRESSLER:

The next speaker is Mr. H. C. Diehl, the director of The Refrigeration Research Foundation.

Advantages of Cold Storing Rations

H. C. DIEHL

The Refrigeration Research Foundation

We should keep always in mind the finiteness of the life span of packaged rations in the sense that they are not everlasting in their acceptability. There are constantly, even at low temperatures, some changes taking place, but those changes are very markedly accentuated at elevated temperatures.

I want to refer at the outset to a graph (fig. 1)—the old Van't-Hoff Curve—which illustrates that there is a rise or geometric advance in the reaction rates of chemical processes, physical phenomena, and bio-

logical phenomena as temperature rises. These reaction rates increase approximately two-and-one-half times for every 18° F. rise in temperature. The graph explains simply and emphatically why the commodities lose quality rapidly at high temperatures. The curve applies to insect behavior, bacterial behavior, chemical processes, and a great variety of phenomena, and portrays the role that storage temperature plays in the rate at which deleterious reactions in foodstuffs progress. This factor of temperature is obviously modified at times by other considerations. Humidity in some products has a marked effect—a rising humidity or increasing moisture content in the foodstuff brings with it a tendency toward more rapid deterioration. This was pointed out recently by Cosler, Woodroof, and Grant on the behavior of ration components. They also pointed out that if there is a relatively high moisture content in the product, a reduction in storage temperature

FIGURE 1

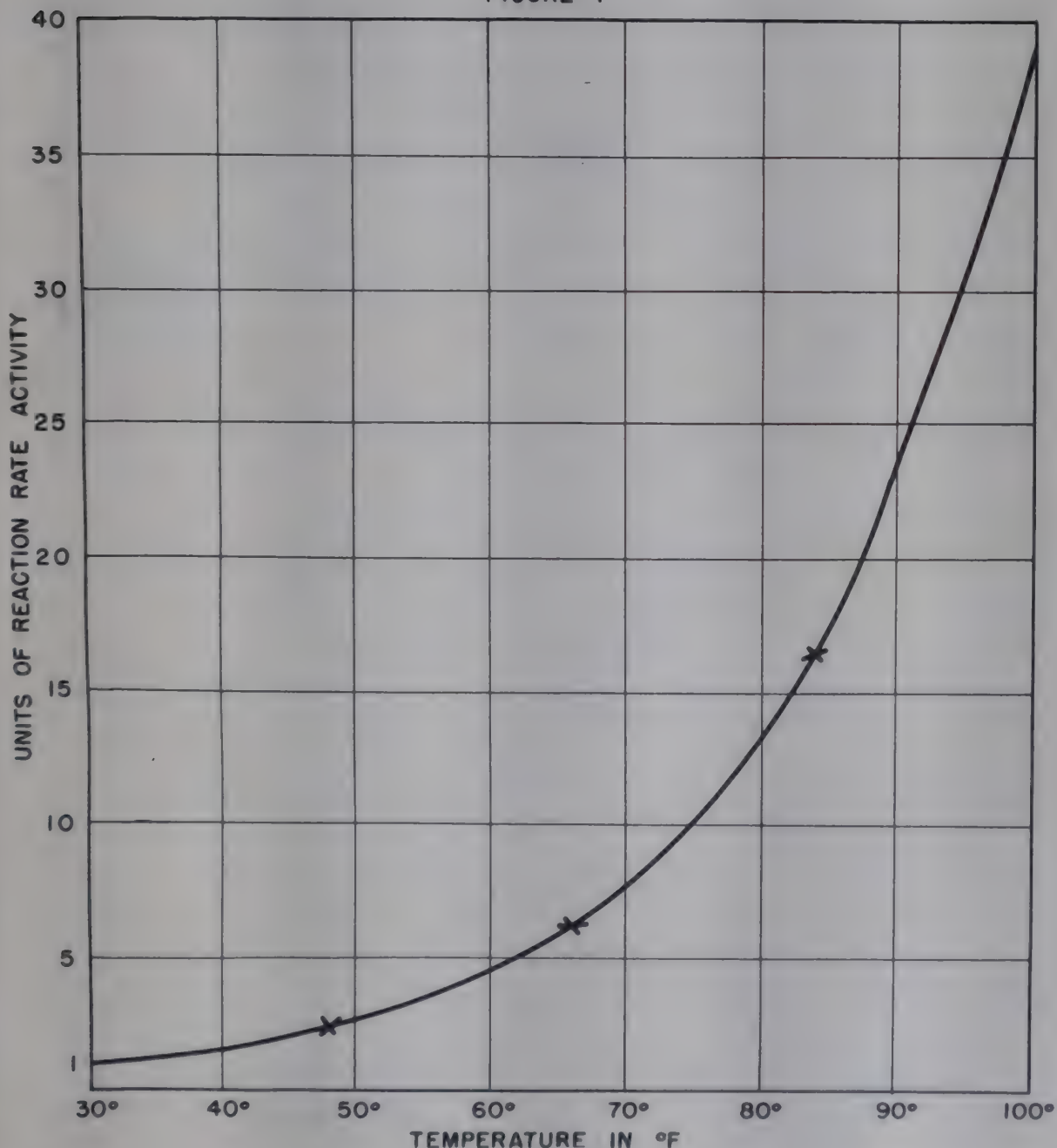
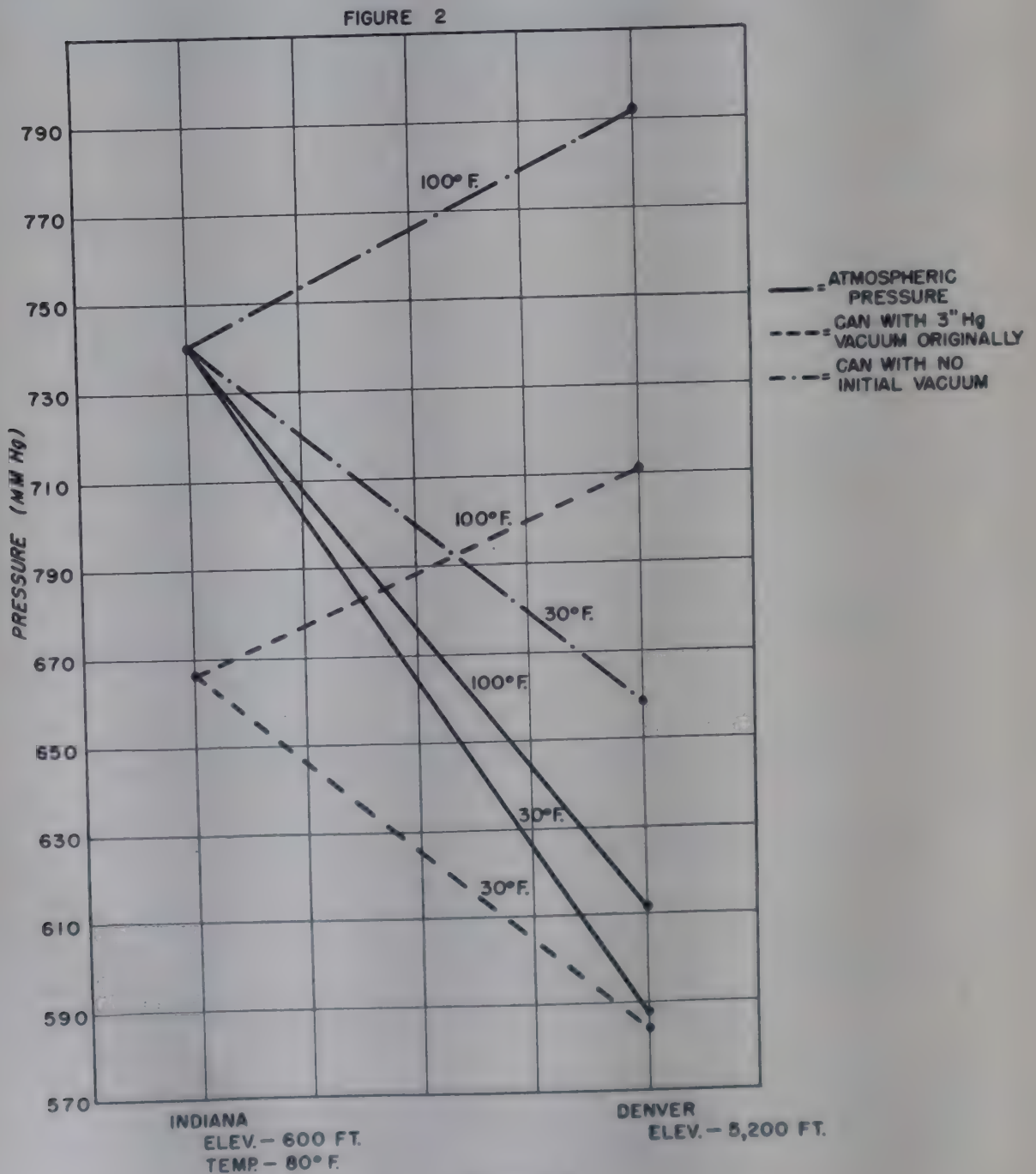


Figure 1.

will offset to a degree the effect of higher moisture content. Reduced temperatures make feasible long-range storage of products such as some dehydrated foods whose moisture content cannot be reduced to levels which would prevent chemical reactions at higher temperatures.

Reduction of temperature also has an effect upon the vacuum in canned goods. The existence of internal pressure in canned goods is presently used as one of the indicators of quality. Many packs may be rejected as spoiled when the can has become a "flipper" or "springer" because of low atmospheric pressures and high temperatures. The gas pressure inside a closed chamber, such as a No. 10 can of tomatoes, is affected only by and varies directly with temperature (assuming the absence of gas producing bacteria). The pressure outside the can or atmospheric pressure varies not only with temperature but with the



Date		Description		Amount	
1890	Jan 1	Balance		100.00	
	Feb 1	Received from A. B.		50.00	
	Mar 1	Received from C. D.		25.00	
	Apr 1	Received from E. F.		75.00	
	May 1	Received from G. H.		100.00	
	Jun 1	Received from I. J.		150.00	
	Jul 1	Received from K. L.		200.00	
	Aug 1	Received from M. N.		250.00	
	Sep 1	Received from O. P.		300.00	
	Oct 1	Received from Q. R.		350.00	
	Nov 1	Received from S. T.		400.00	
	Dec 1	Received from U. V.		450.00	
	Total			2000.00	

altitude, humidity, and weather conditions. Canned goods that may have no positive internal pressure or actually have a vacuum with one set of external pressure conditions may have enough internal pressure in excess of atmospheric pressure at higher temperatures and/or altitudes to cause extension of the can ends.

An illustration of this point may be seen in figure 2. Two No. 10 cans of tomatoes, one with no vacuum and one with three inches of vacuum, are filled in Indiana and shipped to Denver. In this example, the product and ambient temperature in Indiana was 80° F. Upon arrival in Denver, the product can be stored in a warehouse where the product temperature could reach 100° F. with high outside temperature, or in a refrigerated warehouse held at a constant 30° F. This chart shows that both cans at 100° F. will have internal pressures enough in excess of atmospheric pressure to cause a "flipper" condition (2 pounds per sq. in. pressure or 102 mm. hg. is thought necessary). Likewise, it shows that if the two cans were stored at 30° F., this danger of throwing away unspoiled product because the can was swelled is avoided.

This is not necessarily a great discovery, but it is brought to your attention inasmuch as there may be some discarding of foodstuffs which are still perfectly edible, on the basis of apparent spoilage as evidenced by the container.

Corrosion is another spoilage factor that is minimized at the lower temperatures. At 32° F. the effect of corrosion upon the internal surfaces of metal containers is reduced to practically *nil*.

By the use of refrigerated temperatures, you are able by logistic dispersal to predict for yourselves what life that product may have if it is later dispersed and used in ambient atmospheric environment. Obviously, it is not present policy to have mechanical refrigeration in combat areas. But, by employing refrigerated temperatures for canned food storage, it is possible to predict more accurately the presumptive life of the item because its condition in storage can be maintained very nearly like its initial condition—depending, of course, on the length of the period of refrigerated storage. In other words, stockpiling under refrigerated storage provides a control over that item.

Another advantage of refrigerated storage is the reduction of manufacturing peaks. This may be applicable to those commodities which are more perishable than would be implied by the term "semiperishable." Many facets of the food industry find it advantageous from the standpoints of labor availability, cost, and equipment availability to stock refrigerated commodities under refrigeration for use at a later period rather than at the peak of production.

There is also the advantage of less inspection. Some inspection is essential as Dr. Mrak has indicated, but under reduced temperatures there would be no need for repeated inspection and the use of manpower this implies. In the controlled refrigerated environment, the

performance of the commodity can be predicted because of the adequate fund of information available.

Finally, there is the elimination of the intrinsic waste in the deteriorated products. I am told there is a point at which military ration items are either discarded or "force-fed." That is, in a sense, a waste because it is obvious the product has deteriorated or is approaching deterioration at that stage. With the cost of manufacturing and the pressure on raw materials, especially in emergency times, such waste should be eliminated. Where one has prepared a product initially of known and acceptable character, it should be carried through to the maximum desired limit in Armed Forces use.

I think a good case could be made before a Congressional Committee for funds for refrigerated storage because there is ample information to justify its use for certain types of military foods. Certainly the maintenance of optimum nutritional quality and acceptability is in the national interest.

Thus far, some of the major advantages have been summarized. There are some problems too. The condensation problem is inevitable. That subject and the result of intensive researches regarding its control will be discussed by Dr. Woodroof and Prof. Kayan who are conducting their work in this area under grants from The Refrigeration Research Foundation.

A second problem is the cost of storage—a factor that should be approached frankly and with intelligence. Those advantages gained by refrigerated storage must be paid for since there is a service rendered—whether it is done in a warehouse owned by the Armed Forces or in a public warehouse. A cost still is involved, although that cost, in my opinion, is not commensurate at times with the losses involved by forced issue or discarding of food items stored at ambient temperatures. In some cases, also, the packaging may be somewhat more costly when refrigeration is used, because there must be protection against condensation. We find that packaging is an important factor in reducing the adverse effects of condensation. Therefore, packaging must also be reckoned with as a cost factor.

Another problem might be the availability of transport equipment. If you store at reduced temperatures then obviously you are going to transport at reduced temperatures. Whether reefer cars or reefer trucks would be available in time of emergency as readily as boxcars is a transportation problem that may have to be faced.

There is still another matter to which I have heard reference—the supposed rapid deterioration of products after removal from cold storage. People who have performed research for several years with reference to this can provide no evidence that cold storage products deteriorate more rapidly than fresh products of similar quality. There are, however, some things that will have to be taken into consideration. At the time the product emerges from cold storage, it

may perhaps have been held for a very long time and therefore lost some of its original quality. However, within predictable periods of time, the refrigerated foodstuffs are still very much like the originally packed product, and behave after storage as they would have initially if they were held in unrefrigerated ambient temperatures.

Not long ago, the Production and Marketing Administration conducted a survey as to whether shell eggs deteriorated after storage faster than before storage. It was found they did not; the rate of the comparative decline of eggs before and after storage was no different.

In the case of white potatoes which are stored at too low a temperature, sugar accumulates. The rate of decline is higher, then, at the time they emerge from the low temperature because of the availability of the sugar for respiratory purposes. This is not true of white potatoes stored at a proper level of temperature. For fresh products, specifically white potatoes, this is wholly an avoidable sequence, if one stores the product under proper conditions in the first place. These facts are known.

With regard to frozen foods, too, there seems to be some feeling that refrigeration injures quality. The facts are that blanching of vegetables tends to make them more responsive to bacterial degradation. Therefore, after a vegetable is blanched, the nutrient materials are to some degree leached out of the product and there is a dispersal of those on the surface. Hence, bacteria have ready access to food if post-storage temperatures are unfavorable. But this is not the fault of refrigerated storage.

Dr. Mrak very properly referred to the different emergency conditions under which reduction of temperature is obtainable. I think the point was well made. There are things that can be done with ambient cool air, night air, and so on which are helpful. However, to look at the other side of the picture, if products are of substantial value and of substantial importance, then long-range stockpiling should not rest on the temperature vagaries inherent in emergency conditions. One may have to use the latter, when nothing else is available, but usually there is ample mechanically refrigerated storage available for doing the job right. If these commodities are in the care of professional warehouse people in the Armed Forces employ, or with public warehouses, one benefits from supervision which is skilled through years of experience in maintaining the proper conditions for products in storage. Thus, while Dr. Mrak's presentation is very acceptable and very desirable under emergency conditions, long-range stockpiling definitely calls for a mechanically refrigerated warehouse or an organization which understands the problem in order to insure that maximum professional efficiency is devoted to maintenance of the products in the best possible condition.

Finally, as a representative of The Refrigeration Research Foundation and the cold storage warehousing industry which in large measure supports it, I want to offer our full cooperation to any storage problems the Armed Forces have. As Dr. Tressler has indicated, we have a rather extensive experience with a wide variety of items, both in the food and non-food fields. That information, when it can be useful, is at the disposal of the Military. I will say further that if our research projects have any elements which can be modified to give some answer in line with the interest of the Armed Forces, then we will, within reason, modify any of these projects to help obtain the answers required.

CHAIRMAN TRESSLER:

Dr. Harry E. Goresline of the Quartermaster Food and Container Institute, next on the program, will discuss why it is important to consider field ration items and vegetable juices as semiperishable and also indicate perhaps what rations and ration items can be stockpiled for a 5-year period. He will also consider how field rations should be stored if they are held for longer than 2 years.

The Handling of Semiperishable Subsistence

HARRY E. GORESLINE

*Food Laboratories, Quartermaster Food and Container Institute for the
Armed Forces*

Ever since man's beginning there has been a search for ways to lay up food in times of plenty against a time of need. Early man learned the hard way of the existence of certain rules that governed the storage life of his food. He found that, in order to successfully store grain, certain rules with regard to maturity, moisture content, ventilation, and freedom from insects had to be followed. To preserve by fermentation, the acidity or the alcohol content had to be maintained, and in order to keep dried products they had to be kept free from moisture. Man learned when he had to exclude air and when the free entry of air was necessary. In almost every method discovered by trial and error there were defects, and, because no way was found to overcome these, in due time they became accepted as a part of the process. For example, the rancidity of fats is an accepted fact in the food products of peoples who have not developed their technology.

The development of heat processing by Nicholas Appert gave impetus to the development of technological methods that have propelled us forward until today the storage life of most foods consumed by man has been markedly extended—in the fresh state as well as in the "preserved." Such developments have made the job of feeding an Army

much easier and more sure, and the improvements in the methods have become of major concern to the Armed Forces. The establishment of the Quartermaster Food and Container Institute for the Armed Forces was for the purpose of meeting the military needs as they arose.

Oddly enough, with the development of efficient processing methods there has come a relaxing of vigilance in the handling of food products. Raw and perishable products may be handled with care and alacrity, but as soon as the form is changed to that of a can or a box the idea arises that "Now we don't have to worry." Also, each development that extends the storage period of a food seems to give rise to a desire to further extend the storage period. Such is often the case with regard to ration items used in the feeding of troops in the field. Control of temperature and humidity and protection from the elements are often impossible. Accordingly, the ability to withstand deterioration must be "built into" the item. This desire or necessity has led to extensive research programs and the subsequent development of items of markedly superior keeping quality. Many of these developments go far beyond the requirements for civilian storage and marketing because the conditions of military necessity are often in excess of anything encountered in ordinary distribution.

The objectives of these research programs have been to improve the ration item to make it more acceptable to the soldier and to "build in" factors that will retard the rate of deterioration even under the most adverse conditions. In order to have something to shoot at, an objective of 6 months storage at 100° F. without marked deterioration has been chosen. The severity of this test would be encountered only under unusual conditions, but it is believed that, if possible, foods should be made capable of withstanding even these conditions. Thus the search goes on. In some cases the solution has been found in the adding of compounds which retard the deterioration, such as adding antioxidants to fatty materials. In other cases it has been necessary to take something away, as in the removal of sugar from eggs to prevent the browning reaction during storage of the dried product. Low moisture, gas packing, etc., have also been found of great help in the search for greater stability.

One of the most important factors found to extend storage life is temperature. Everyone who works toward the objective of stability for 6 months at 100° F. realizes that the storage life is markedly extended at temperatures less than 100° F. As an example, let us take the rate of deterioration of crackers as measured by the acceptability. If we analyze the rates of deterioration during storage at various temperatures, it is found that the approximate point of acceptability reached in 1 year at 100° F. requires 2 years at 70° F. and 3 years at 40° F. to reach the same point of deterioration. Thus, the storage

life of ration stocks can be markedly extended by the device of lowering the storage temperature.

To predict the storage life of any ration item, the conditions of storage and the temperature must be known. Conversely, to reach any set objective with regard to desired length of storage, the conditions and the temperature must be selected. One cannot logically set a storage period at 2 years, 3 years, or 5 years without knowing the characteristics of the items and the storage conditions and temperatures that will be available. Dr. Mitchell has pointed out the effect of temperature on the rate of deterioration and showed that it is impossible to obtain long-time storage of most items unless strict attention is paid to the temperature of storage. This important factor must be taken into consideration in planning any storage program.

In times of active military action the conditions of storage and rate of distribution can seldom be chosen at will, but rather must be accepted as they come. Also, there is need for some stockpiling of food against the necessity of a sudden call for large amounts of subsistence. No one can discount the need for highly stable items to withstand the rigors of such activity in the field, but on the other hand there is need for better planning to take advantage of the facts that we know during the period leading up to the emergency. Peacetime or "stockpiling" periods offer the chance to carry the stocks in good condition until the time of extreme need, through taking advantage of this available technology. By proper processing, low-temperature storage, and rapid methods of handling, the quality of ration items can be maintained over periods far in excess of that to be expected when no attention is paid to those factors. To some persons, cans or boxes of food are just so much cord-wood, and about the same care is taken in the storage of the 2 types of items. It is often necessary to develop an educational program to instill into the minds of those charged with the actual storage a high regard for the storage requirements of various ration items, and to demonstrate the effects of indiscriminate storage.

All foods do not deteriorate at the same rate under a given set of conditions. This poses a problem when a ration (such as the C Ration) contains in the same package items of good stability and those of rather limited stability. If certain items have been stored for a period before assembly and others have not, or if items of limited stability are included in the pack along with the good, there is always the chance that the acceptance of the entire ration will be markedly altered by failure of the items of limited stability. The failure to properly protect and store the lower stability items before assembly, thus lowering their acceptability prior to inclusion in the ration pack, will give rise to a problem which can easily cause trouble in a storage program. Such problems can be solved only through proper selection

of items, adequate protection of all items against deterioration between manufacture and the assembly of the pack, and the proper storage conditions during the storage period. The seriousness of the situation has been reflected in the consideration of assembling rations only just before issue instead of at the beginning of the storage period.

The effect of type of component and of storage conditions on the acceptability of a ration may be illustrated by reference to a report of a survey on the deterioration of stored C Rations. These rations were stored at three southern depots under prevailing dry warehouse conditions. Complaints were received on the deterioration of two components and samples of the C Rations were drawn from the three locations. The deterioration of the 2 components was found to be such as to make them inedible and was due to container failure. However, upon examination of the other components in the pack it was found that 12 components had deteriorated to a point where it would be impracticable to replace the two items and issue the ration. The report on this investigation states, "The planned stability of these lots has been exceeded by conditions and period of storage experienced"; again, "Because of the large number of seriously deteriorated units in these rations, they would not be the equivalent of complete rations at point of consumption even if components were replaced"; again, "The entire ration has become unfit for use under combat conditions due to prolonged and severe storage conditions." It is interesting to note that all this took place in a period of 2 years.

It may be true that money was saved by selecting ordinary warehouse storage, but the entire lot of rations was lost. Not only was there an economic loss, but also a shortage in the planned food reserves of the Armed Forces resulted. Had these rations been stored at 40° F. they would be usable at this writing and for some time to come. As Dr. Mitchell has pointed out, it is not necessary to use zero storage or even 30° to 33° F. to increase the stability of most food items. It is true that the lower temperatures do markedly extend the storage life, but temperatures of 40° F., or even as high as 70° F. show remarkable retardation of the rate of deterioration. If the fact can be put across that rations are truly perishable, and those who plan ration programs convinced of the value of cool storage, an overall monetary saving can be realized and a worth-while addition made to our available storage stocks.

Selective storage offers much in solving the problem of maintaining a good uniform balance of quality in ration items. Those items that have good keeping quality may be stored at temperatures that give long storage life, yet keep the cost of storage at a low figure, while those items known to deteriorate rather rapidly at the higher tem-

peratures may be stored with profit at lower and more costly temperatures. Thus, 2 items of markedly different stability may be put in storage at the same time, kept at an equal acceptability by means of selective storage and be available for use in a ration assembly program for immediate issue.

The question has been asked as to what ration items may be stored for 5 years. The answer is that we probably have none if the storage is at temperatures around 100° F. In order to have stable ration items for a 5-year period, the storage must be made at much lower temperatures. Many items will maintain stability for 2 years at 70° F., but in order to last 5 years the temperature must be dropped to at least 40° F. and preferably to 32° F. Such items as crackers, starch-jelly discs, canned sweet potatoes, dehydrated diced potatoes, glucose-free dried eggs, cheese spread, sandwich cookies, and many other items will withstand 5 years of storage at 40° F. or lower. Results indicate that if stored at higher temperatures many of them will last for 2 or 3 years but will not last for 5 years.

In summarizing information on storage stability, it may be pointed out that: (a) ration items of every type are perishable; (b) their storage life is dependent upon the temperature at which they are stored; (c) the rate of deterioration under any set of conditions is not the same for all items, and a variety pack will not be of uniform quality after storage; (d) lowering the storage temperature to 40° F. or lower will markedly increase the storage life; (e) raising the storage temperature to around 100° F. is disastrous to quality and in most cases reduces the useful storage life to 6 months or less. These facts point to the necessity of a realistic approach in planning the storage of subsistence, as forced issue of marginal rations is not the answer to the storage problem.

CHAIRMAN TRESSLER:

We have not only the problems of storage, but also those of handling and transportation. When Mr. W. L. Porter of the Environmental Protection Division, QM R&D Command, reported on his studies for the past 2 years on the temperatures which may be found in stationary and moving boxcars, I thought this conference would not be complete until we had that story, because if the rations are going to be ruined by moving them across the country in boxcars at 140° F., there is no reason to put them in cool storage at 40° F. and below. Mr. Porter has come here today to give us a preliminary or progress report on his studies in this field.

Transportation Problems—Occurrence of High Temperatures in Standing and Moving Boxcars

W. L. PORTER

Environmental Protection Division, Quartermaster Research and Development Command

I have been very much interested in listening to the rest of these speakers, because they have talked about conditions which can be achieved by altering domestic storage conditions and some overseas storage conditions. They have been talking about how to make it easy on the rations. I am going to talk on how tough it can get on the rations in the conditions which have been referred to as "adverse field conditions" or "extreme stress conditions," and the particular target is: What sort of testing temperature should be used as a final testing temperature? We spoke of 6 months at 100° F. What sort of temperature should be used, not with an idea of acceptability after 2 years storage, but just for this "all or none" change which we have heard Dr. Woodroof mention in connection with the crawling of greases from chocolates?

Statement of the Problem

In connection with the present discussion concerning optimum conditions for the storage and handling of semiperishable subsistence items, the Environmental Protection Division, QM Research and Development Command, has been asked to make a preliminary report upon an extensive study of the occurrence of high temperatures in standing boxcars undertaken during the summer of 1953 at Yuma, Arizona, and Cameron Station, Virginia.

The present project was initiated as part of Research Project 7-83-02-009 in June 1952 at the request of representatives of the QM Food and Container Institute for the Armed Forces. In essence, the stated problem was to conduct surveys of temperature trends within shipholds, railroad boxcars, and warehouses for use in analyzing effects of temperature on packaged food items during shipment and storage with special reference to the frequency and duration of temperatures above 100°, 110°, 120°, and 130° F. A second part of the problem was the determination of world-wide frequency and probability of occurrence of ambient air temperatures above the limits stated in order to develop a method of correlating storage and transit conditions with ambient conditions.

History of the Problem

Theoretical considerations. The problem as stated was of necessity defined in general terms. Research personnel of the Division, after consulting the literature and history of previous work, became convinced that the answers requested could not be simply stated and involved fundamental philosophies of testing. In essence, definition of terms like temperature trends, effects, etc., used in the problem depends upon a definite statement of what action is to be determined by the results and what type of results will be significant in terms of that action.

Such a definite statement requires answers to three questions: (1) What testing method is used to simulate field conditions? (2) Is design or acceptance predicated upon a calculated small loss or upon the assumption that products must be capable of storage at any observed extreme, providing that the extreme is observed at a position and under conditions in storage analogous to that which confronts the tested product in a laboratory? (3) Is it desirable to test in different ways products for diverse geographic areas, or for different modes of storage or transport? Although these questions seem self-evident, it has been found that, as in the present problem, they have separately or together often been neglected in the demand for a simple, general, all-embracing statement of climatic extremes.

A host of additional questions is implied by the fundamental three. For example, in the case of packaged subsistence, is it reasonable to assume that individual, unpackaged cans of beans should be subjected to temperature regimes in testing ovens like those which prevail in the hottest air at the top of any conceivable storage space? Beans in storage or transit will almost always be packaged in fiber containers with dead-air spaces and moderate radiation shielding, which act as effective heat-transfer barriers. A survival ration, on the other hand, which may be placed in dark metal containers within three inches of an airplane wing surface, might very well be tested under such a regime. Thus, the point of temperature measurement with relation to the subsistence in field conditions is critical.

In addition, is so-called calculated risk a more compelling standard for setting testing regimes than the possible deterioration of even the smallest fraction of subsistence shipped? It is argued that any such deterioration might through spoilage, lowered nutritive value, or unacceptability, prejudice the effective operation of troops in the field. However, design for less than observed extremes based on calculated risk allows much greater diversity of items, lowered cost, and heightened initial acceptability.

In attempting to estimate probability of deterioration of a given item, a great number of logistic situations must be considered, even

with the assumption of a static logistic picture. Alterations of this picture in the future make calculation of probability of deterioration complex in the extreme.

Lastly, the determination of correlation with ambient conditions will have value under either of two suppositions: (a) that predictive formulas may be derived which will enable extrapolation beyond the range of the data available, in order to determine absolute extremes in remote areas of maximum heat stress, or (b) that the geographic area and the method of shipment and storage may be determined for certain items, facilitating differential testing.

Research personnel of the Environmental Protection Division, after consultation with representatives of QMFCI, have obtained rather definite answers to questions 1 (testing methods to simulate field conditions) and 3 (testing products differentially). Oven testing of individual products in cans, or ration packages, rather than in shipping cartons is the rule. Temperatures within air spaces in cartons have therefore been those sought in the field to simulate oven conditions. It also appears that it is not now possible to determine in advance the route, destination, or method of storage and transport for any important QM subsistence items. Therefore, correlation with ambient conditions has been pursued only to obtain estimates of storage conditions in world-wide areas of extreme heat stress which are remote and inaccessible for research.

The question of calculated risk vs. extremes has not been answered. The answer to this question is fundamental to analysis of the data gathered this summer and to other available data. Having no definite answer, and aware of the logistic intricacies involved in calculated risk, we have up to the present sought extreme values, where measured in situations analogous to test-oven conditions. We have felt that if such extremes can be shown to be within present testing ranges, or if relatively simple techniques of storage can bring them within these ranges, there is little need to assess the calculated risk.

History of problem prior to assignment as a phase of Project 83-02-009. High temperature occurrence in storage and transit has been intermittently the concern of Quartermaster research and development since the beginning of extensive operations in the Pacific in 1942. During the summer of 1943, two tests of temperature in open and covered dump storage were conducted—one at Blue Hill, Massachusetts, and a more ambitious and carefully instrumented test at Blythe, California, in the Sonoran Desert. This area, including the region from Yuma to Death Valley, had been selected as the nearest American analogy to hot-dry conditions productive of extreme heat accumulation in storage in the Sahara and in Iran. In this study, there was recorded a maximum temperature of 126° F. within the air in the top center carton of a tight-tarpaulin-covered dump, which

was a 5-foot cube of cases of canned peas. Ambient temperature was 113° F. Temperatures in the air under the tarp cover reached nearly 150° F. Temperatures over 120° F. were sustained in the carton for 4 hours. Food temperatures were not measured in this carton, but rather in a larger stack where a food temperature of 115° F. was attained in canned luncheon meat with a carton temperature of 117° F.

In spite of these extremes, in so many of the cartons tested were the maximum temperatures near 100° F. that it was recommended that storage of foods at 100° F. (surrounding tested item not in case) be accepted as a suitable laboratory approximation to storage in hot climates.

A field study of fungus in moist-tropical storage was conducted during the following summer at Indian Bay and Gainesville, Florida, in which Dr. Miller, also of the Environmental Protection Division, handled the climatological and heat measurements. Exhaustive readings were taken of temperature and humidity in storage dumps, of accompanying solar radiation, and numerous climatic variables within exposed and covered stacks. It is interesting that in this study, the inside surface in the top carton of a tightly tarpaulin-covered dump reached a maximum of 125° F., similar to the Blythe maximum. On 15 percent of days between 15 September and 9 October, maximum temperatures greater than 120° F. were reached at this position. It is also noteworthy that temperatures of the covering tarpaulin were between 150° and 160° F.

Confirmation of these results was obtained from replies to a questionnaire distributed to actual Quartermaster storage dumps in locations of extreme heat accumulation all over the world in the summer of 1945. Both hot-dry and hot-wet situations were embraced in 19 replies from the India-Burma-Iran area, from the Caribbean, the Canal Zone, and the Southwest Pacific. At Saipan, air in the top carton of a tarp-covered dump reached 125° F., when free-air temperature was 89° F. Food temperature was 110° F. Credence is lent to these values by very similar results from a station in the Palau Islands. Only one desert station, Khorramshahr, Iran, replied. Case-air temperature reported was 102° F.

An extensive Army Air Force Tropical Science Mission in 1945 provided some additional data on storage temperatures in tropical conditions of extreme heat, but added nothing to the extremes previously mentioned, although many types of storage in field conditions were observed.

It will be noted that only in the Blythe study was there an attempt at correlation of the storage temperatures with ambient conditions. This attempt was unsuccessful.

The findings of these studies, scattered reports from the literature of temperatures as high as 160° F. at the top of small inclosed storage spaces in tents and airplanes, and a cursory study, from correspondence, of shiphold temperatures, were incorporated in EPS Memorandum Report No. 10, "High Temperatures and Accompanying Humidities in Transit and Short-Term Storage," 1947. Conditions for simulation of extremes of temperature were set up therein, without detailed specification as to the conditions of packing and placement with respect to the heat source. The figure of 160° F. was recommended for hot-dry storage, 125° F. for hot-wet, and 90° F. for shipholds. The figure of 160° F. was adopted in regulations, but in some interpretations of these regulations, the position of the item with respect to that temperature was largely ignored, as often were the regulations.

Major Virgil O. Wodicka of the Quartermaster Food and Container Institute, at a conference in November 1945 on Deterioration of Fats and Oils, stated that because of the unrealistic nature of the higher limits that had been suggested and the consequent curtailment of available subsistence, the QMFCI laboratory was using 6 months at 100° F. as a measure of suitability of subsistence items for overseas shipment. Although some heat damage has been found in returned shipments from overseas, I understand that this testing regime has continued to the present at the QMFCI.

An ambitious study of temperatures at high and low locations in QM domestic warehouses between 1949 and 1950 yielded no new extremes. Temperatures in the Forth Worth Quartermaster Depot at 15 feet from the floor and as many from the roof reached a maximum of 111° F. This was the highest observed.

History of problem under Project 83-02-009 prior to 1953. When the project was assumed by the Environmental Protection Division in 1952, an extensive survey of the literature was made. Correspondence and interviews were initiated with persons or agencies who might have information on storage and transit temperatures in shipholds and warehouses. This search indicated that previous knowledge of the problem was inadequate and that measurements in the field were needed.

A series of observations was made in an empty boxcar at Alexandria, Virginia, and in another at Yuma, Arizona, in summer 1952. Temperature in cars loaded with dried fruit moving from the Pacific Coast to the Gulf Coast was measured through cooperation with the Department of Agriculture. Report on this research was made in EPD Special Report No. 60, 16 June 1953, in which maximum airspace temperature at top of car was given as 130° F. at Cameron, 138° F. at Yuma, and 134° F. in the moving car. Temperatures in cartons were

obtained only in the transit test. A maximum of 102° F. was obtained in a carton on the day of maximum airspace temperature. Although instrumentation was not elaborate, the results suggested that future tests should be confined to a stationary car, since air motion about 10 mph markedly reduces the maximum temperature produced by a given combination of radiation load and ambient temperature.

Interviews with steamship companies in New York and extensive perusal of their logs in critical heat-accumulation areas like Suez, Panama, and the Southwest Pacific showed no hold temperature in a moving ship greater than 110° F. It was therefore concluded that, except for ships at dock-side (on which little or no data is available), moving ships and boxcars, like domestic and overseas warehouses, may be disregarded in the search for extreme heat stress.

The conditions of extreme stress appear to be the tightly covered dump and the standing boxcar. Inasmuch as the heat accumulation of the stationary ship is analogous to the standing boxcar (steel roof over hatch, steel sides), the smaller airmass of the boxcar offers a situation favoring higher temperatures than the ship, particularly because in ships there is the conduction from side plates cooled by warm sea water rather than hot desert air, and in boxcars the cargo is very near the roof.

Research on temperatures in standing boxcars on sidings at Yuma, Arizona, and Cameron Station, Virginia, was accordingly planned for the summer of 1953 as representative of extreme hot-dry and average humid subtropical conditions, respectively.

Description of Research During 1953

Problem as formulated for the research. Purpose of the boxcar research planned for 1953 was to obtain daily cycles of temperature at representative points throughout a typical load of subsistence in a steel boxcar, in the airspace above the load, and in the airspace in an empty car at an accessible site where ambient conditions and orientation favorable to maximum heat accumulation prevailed. The research was planned to embrace the most extreme 6 months of the year at Yuma and 4 months at Cameron Station, a representative site in an average humid subtropical region.

Analogy to test-oven conditions was sought by measuring temperature of air within the case of subsistence in the load but outside the ration package, which is the item inserted within the oven. This is not comparable to an oven temperature if the can alone be inserted in the oven. However, in separate tests at Cameron it was found that the temperature outside the package and within it at maximum stress are sufficiently similar for this purpose.

TEMPERATURE EXTREMES IN THE UNITED STATES

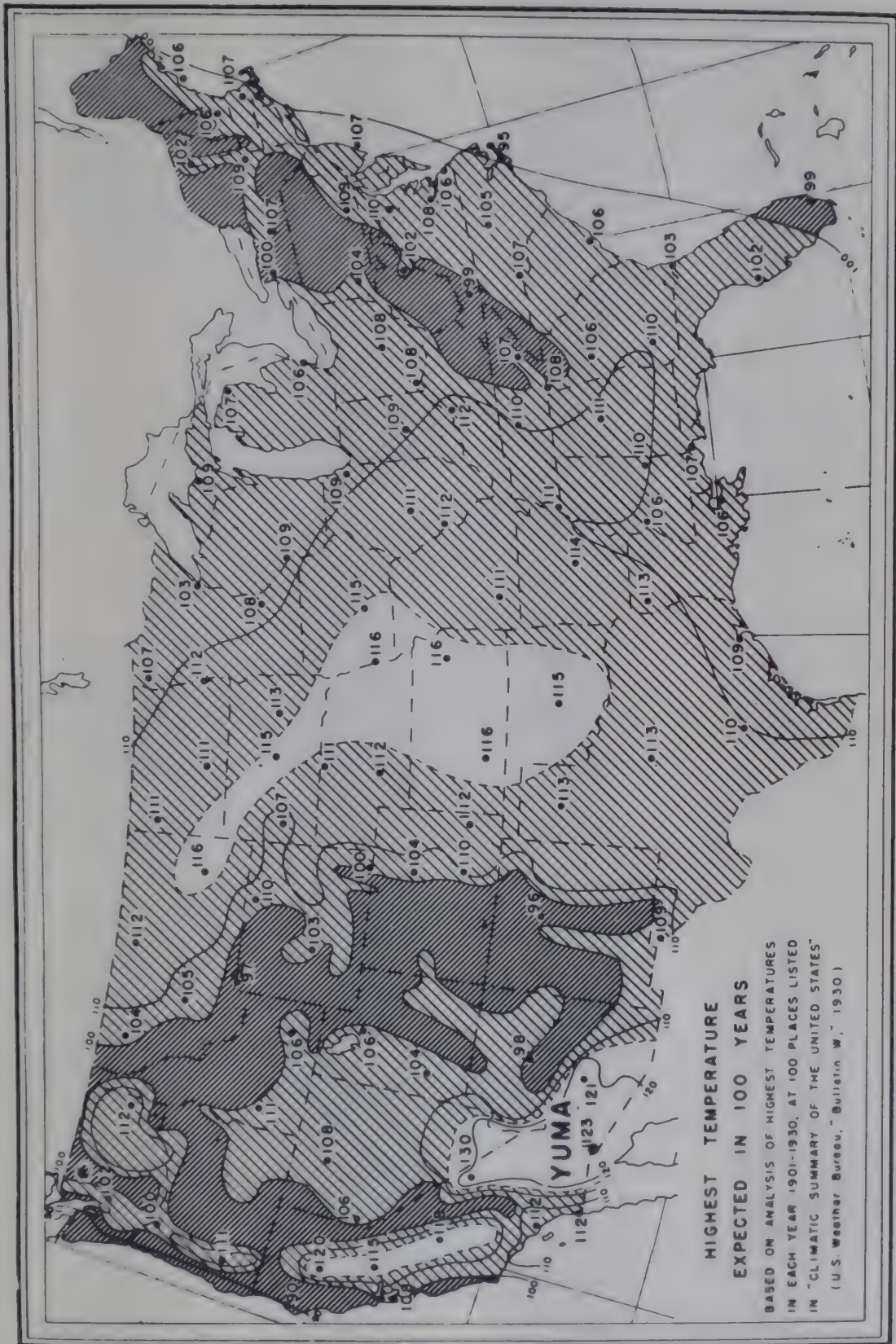


Figure 5.



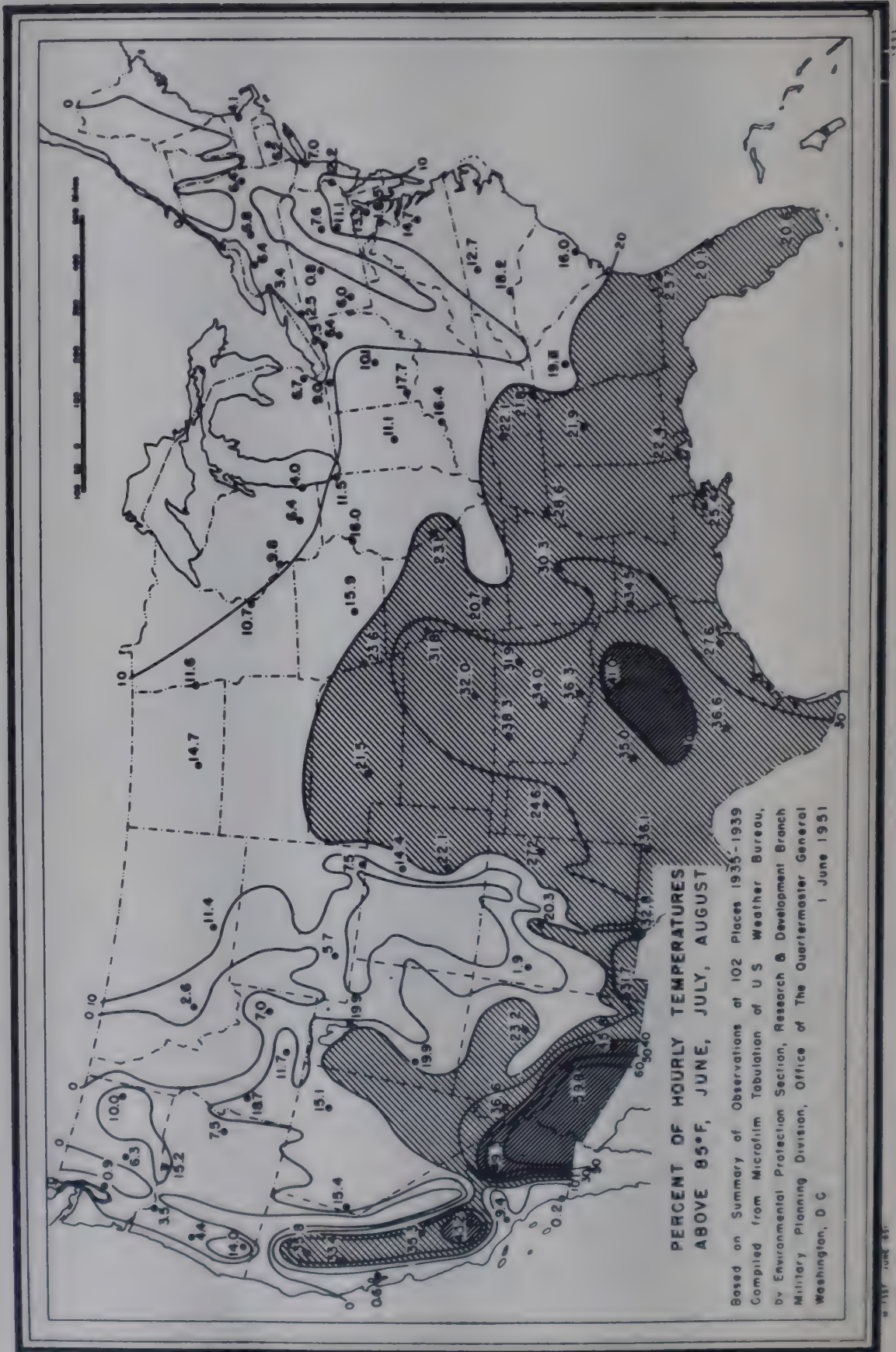


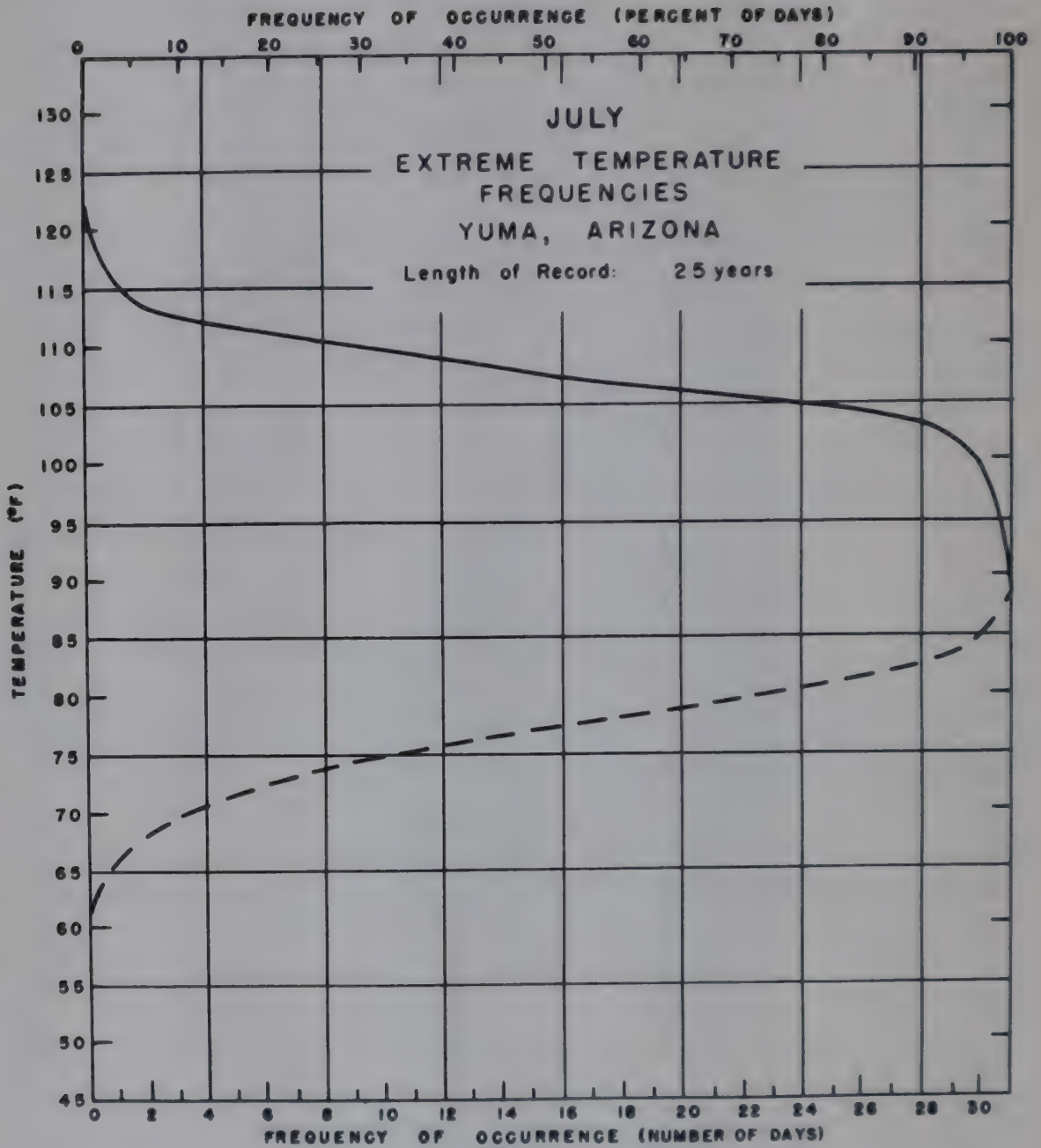
Figure 6.

The gradients prevailing throughout the load and throughout the summer were sampled to determine the relative risk of alteration involved in the temperature behavior of different fractions of the load for different periods of time. Airspace temperatures, temperatures 6 inches from roof and from load, and roof and side-door temperatures were recorded for possible use in testing storage conditions confronting unpackaged and exposed items in railroad cars.

Finally, ambient temperature, radiation, wind speed, and direction were carefully recorded with a view to possible correlation of interior with ambient conditions.

Yuma Research Technique—Climatic factors in choice of site. The factors involved in situations of maximum heat accumulation in a storage space are numerous and their operation not too well understood. Total daily radiation load, hourly radiation load at maximum, mean ambient and maximum temperature, wind speed, and character of ground surface must be considered. After careful consideration, however, it was felt that areas of highest maximum and mean ambient temperature for peak summer days offered the best available index of areas of heat accumulation in storage spaces, since high total daily radiation load (although not highest hourly radiation at maximum) is found here in combination with high air-temperature maxima and means and low-wind speed, a situation which does not prevail in the high-altitude areas of greatest total daily insolation. Highest hourly radiation occurs at any location between the Tropics when the sun is at zenith at noon, but the shorter day cuts down total daily radiation. High-radiation load at noon is correlated with short-duration but extremely high temperatures in skin layers of storage, as at Saipan, mentioned above, but, where all-over build-up of temperature throughout a load over the day and month is concerned, total daily and monthly load is more critical.

Extreme situations are found in three areas: (a) the Sonoran Desert, embracing Death Valley, Yuma, and Blythe; (b) the central Sahara Desert; and (c) the deserts surrounding the Persian Gulf. Comparability of the three areas is shown by figures 1 to 4 indicating world-wide frequency of occurrence of high temperatures and distribution of absolute maxima ever recorded. It should be noted that the Iranian area is one of great strategic importance. The Yuma area was chosen because of its proximity to reliable weather and radiation reporting stations, and its accessibility to the Yuma Test Station and the Signal Corps Field Station No. 2, whose personnel maintained the instruments and made additional ambient measurements. Figure 5 indicates Yuma's position and its relation to other points with reference to the highest temperature to be expected in 100 years, and



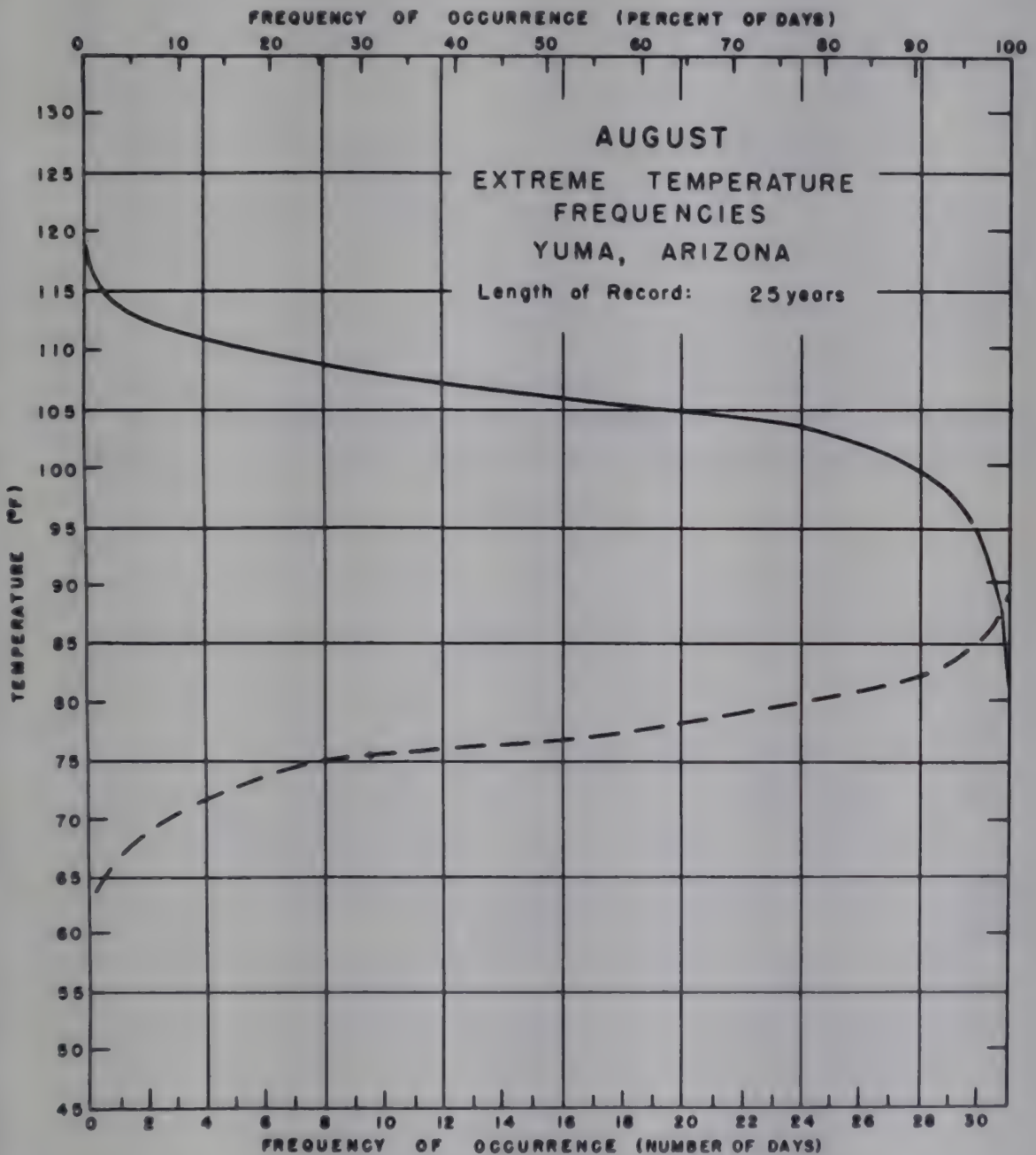
—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

- - - Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 100°F or greater may be expected 29.9 days during July.

Figure 7.

figure 6 reveals percent of time-temperature is above 85° F. in hot months. Frequency of occurrence of maximum temperatures at Yuma during the two months of extreme stress is shown in figures 7 and 8. In July and August, 2 percent to 3 percent of the days may be expected to have maxima above 115° F. The distribution of average solar radiation for critical months and that for cloudless day radiation, as shown in figures 9 to 12, is also of interest. Yuma is one of the stations within the area of high average daily radiation which also experiences maximum ambient air temperatures.

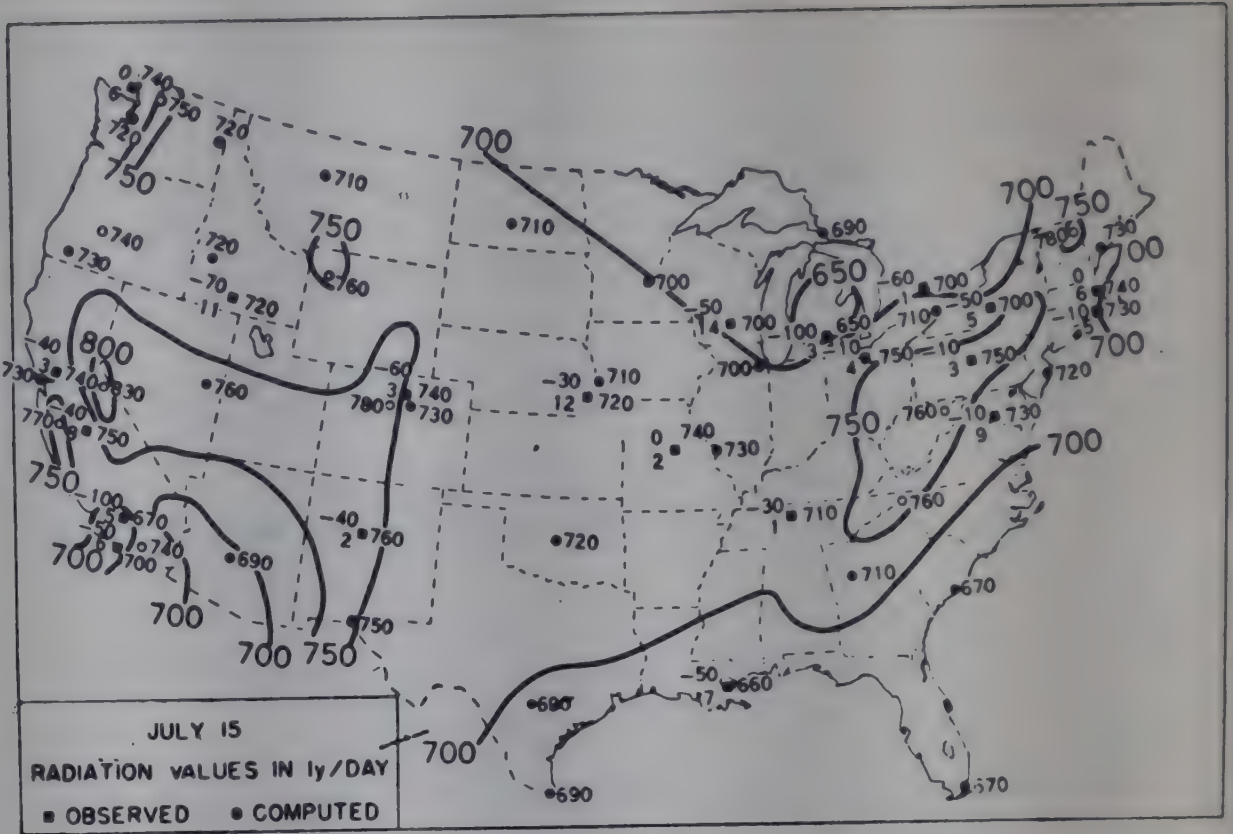


— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

- - - Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 100°F or greater may be expected 27.6 days during August.

Figure 8.



Average solar radiation received on a square centimeter of horizontal surface at the ground on the 15th of each month during cloudless days (unit, ly per day).

Figure 9.

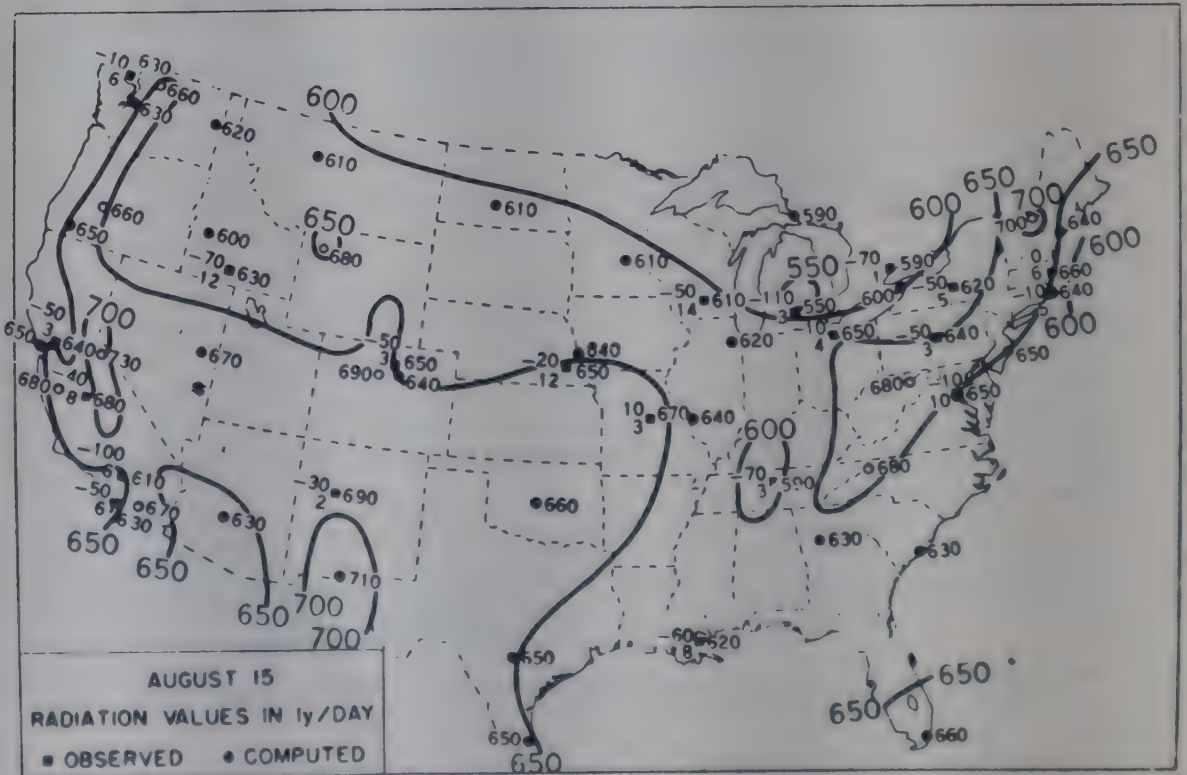


Figure 10.



Average daily solar radiation received on a horizontal surface at the ground (by months) in ly per day.

Figure 11.



Figure 12.

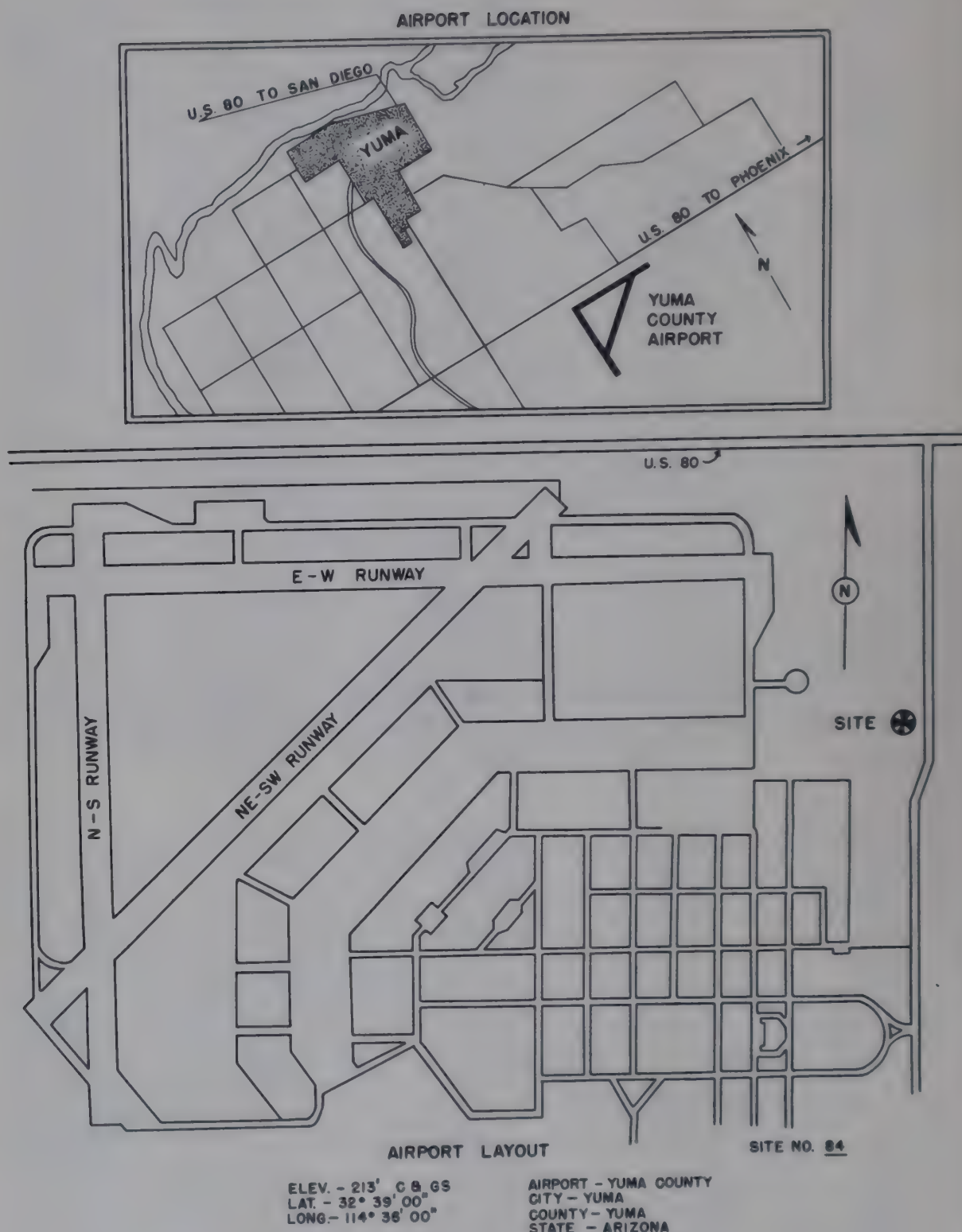


Figure 13.

Site and situation chosen. Having determined the general area for research, a site was selected on the Yuma County Air Base, USAF (fig. 13), which combined accessibility to supporting station and weather observing points, an available railroad siding, power source, and maximum security. The site chosen was on a siding which oriented the loaded car at 205° F. true and the empty car 211° F. true. It had been determined that a north-south orientation would give maximum heat stress, since side walls would be normal to average morning

and evening rays, but this was not attainable. The deviation from true north and normal incidence at first and last light was not considered too great. The surface at the site is light desert sand plain with numerous small rock fragments. Albedo of such a surface at maximum sun altitude has been determined at Blythe to be 25 percent, as compared with 6 percent for black tarpaulin material.

Except for scattered airport buildings, such a surface extends 3 miles north and south of the site and, although interrupted by 2 miles of continuous black-top airfield surface, for 5 miles west and southwest. Beyond this sand plain area to the north and west, irrigated fields extend for 10 miles beyond which is desert sand plain. To the south and east, however, the irrigated area ends 3 to 4 miles from the site, and pure desert sand stretches for hundreds of miles to the south and east.



Figure 14.



Figure 15.

Figures 14 and 15 demonstrate the relative openness of the site and freedom from extraneous radiation sources.

Measurement procedures. Measurements of temperature at various points in the cars was carried out with copper and iron-constantan thermocouples recording on continuous strip charts of 2 Brown Electronic Recorders from 15 April to 21 September. Recorders were



Figure 16

serviced once weekly. Temperature checks reveal that no greater than plus $1\frac{1}{2}$ -degrees error was experienced in the range measured.

Cars were standard steel construction with steel roof covered above and below with dark asphalt, and wooden interior floor and wall sheathing. The wooden sheathing and floor acts as an effective insulator, since it traps dead air between the steel pillars and roof. It is the roof and bare steel doors that are the effective radiators and major heat sources.

The type of load chosen was a matrix of 1,700 cases of string beans, packed in No. 10 cans, 6 to a case. Temperatures were recorded, however, in 8 cases of Ration, Individual, Combat C. Factors of spoilage cost, representativeness of load, and comparability with previous storage tests were considered in the choice. Brine-packed beans, for example, were considered sufficiently analogous in heat characteristics to packed peas used as matrix at Blythe. In addition, this type of load and its mass (81,600 lbs.) were chosen as the most typical Quartermaster subsistence items shipped on the basis of shipment volume (figs. 16 and 17). The car was loaded to a depth of 5 feet, leaving $5\frac{1}{2}$ -feet of storage airspace. This load constituted about four-fifths of the maximum load allowed.

As at Blythe, temperatures were recorded in specially prepared cases. C Rations were used, since it was the request of the Quartermaster Food and Container Institute that the temperatures in the luncheon meat component of this item be recorded under controlled conditions of stress. Results of the Blythe test indicated that in a

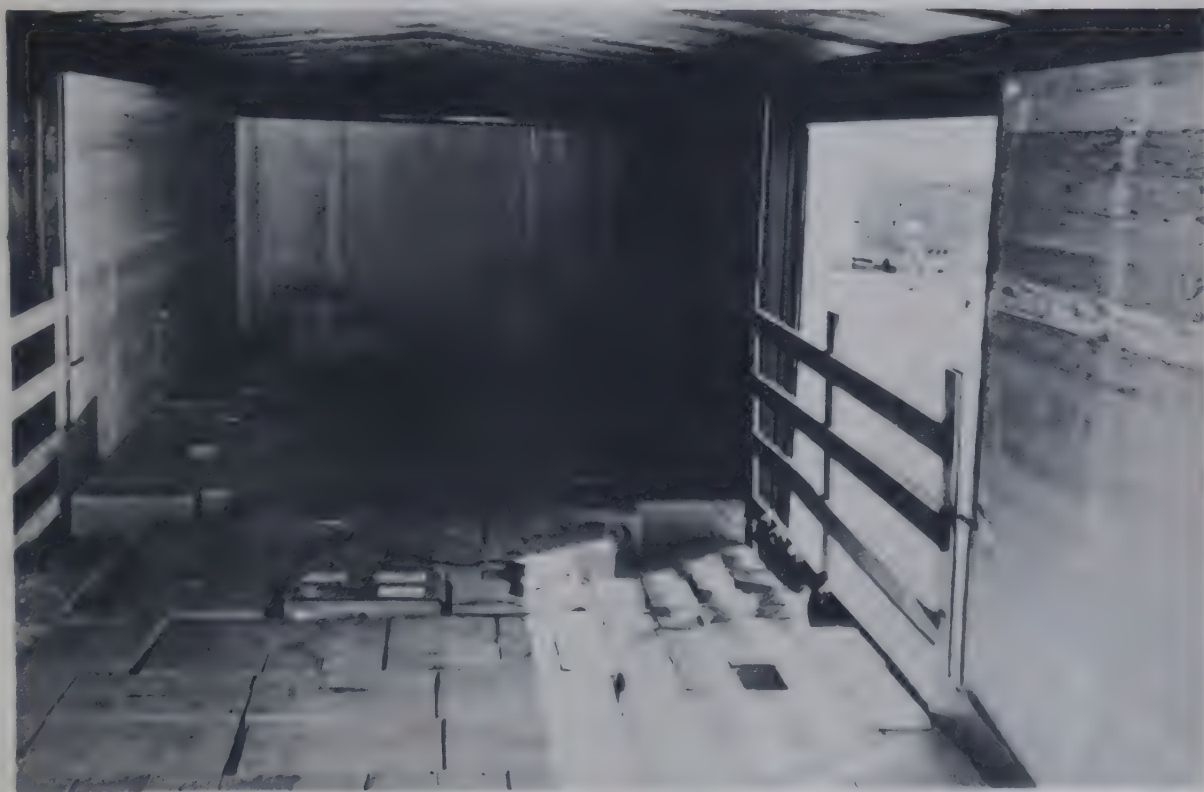
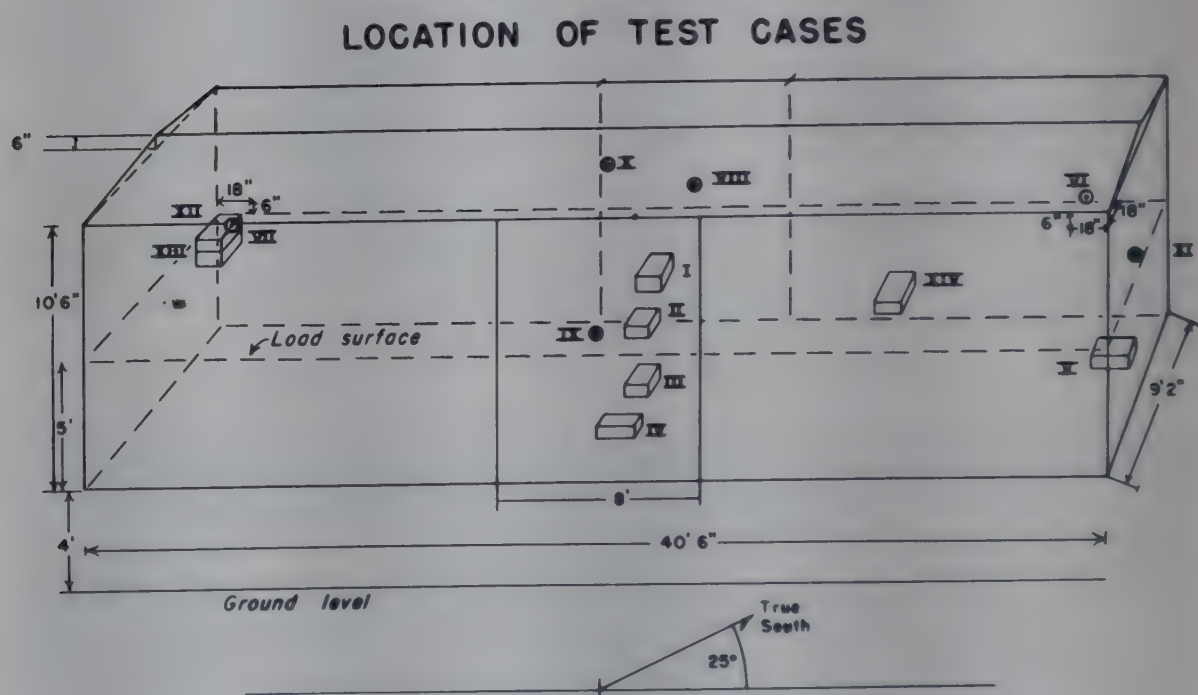


Figure 17

test case imbedded in a homogeneous matrix, no significant differences in mean temperature could be found between luncheon meat, peas, and dehydrated carrots. Where complete small covered stacks of the three aforementioned items were compared at Blythe, mean and maximum temperatures in air in cases of peas were significantly higher, although poor comparability (different type of case, size of stack, and size of can) makes this difference unreliable. It was felt, however, that beans offered a matrix comparable in thermal characteristics to the stack which gave maximum temperatures at Blythe, and that the luncheon meat component of C Ration packages, which yielded an absolute maximum food temperature 5° F. higher than the other two tested in the special cases at Blythe, should be used as the test item.

Temperatures were recorded in eight test cases, spotted as indicated in figure 18 for each of which control cases were withdrawn and re-



YUMA BOXCAR TEST ~ 1953

- Wall surface thermocouple
- Air space thermocouples

Figure 18.

tained at Chicago. Temperature of air in the case was sampled by means of a thermocouple suspended two-and-one-half inches below case top between two central or side packages in a case in which six packages are placed side by side in two lines of three at the same level (figure 19). A wood block was inserted in the package to which the airspace couple was attached. Temperature in the luncheon meat was

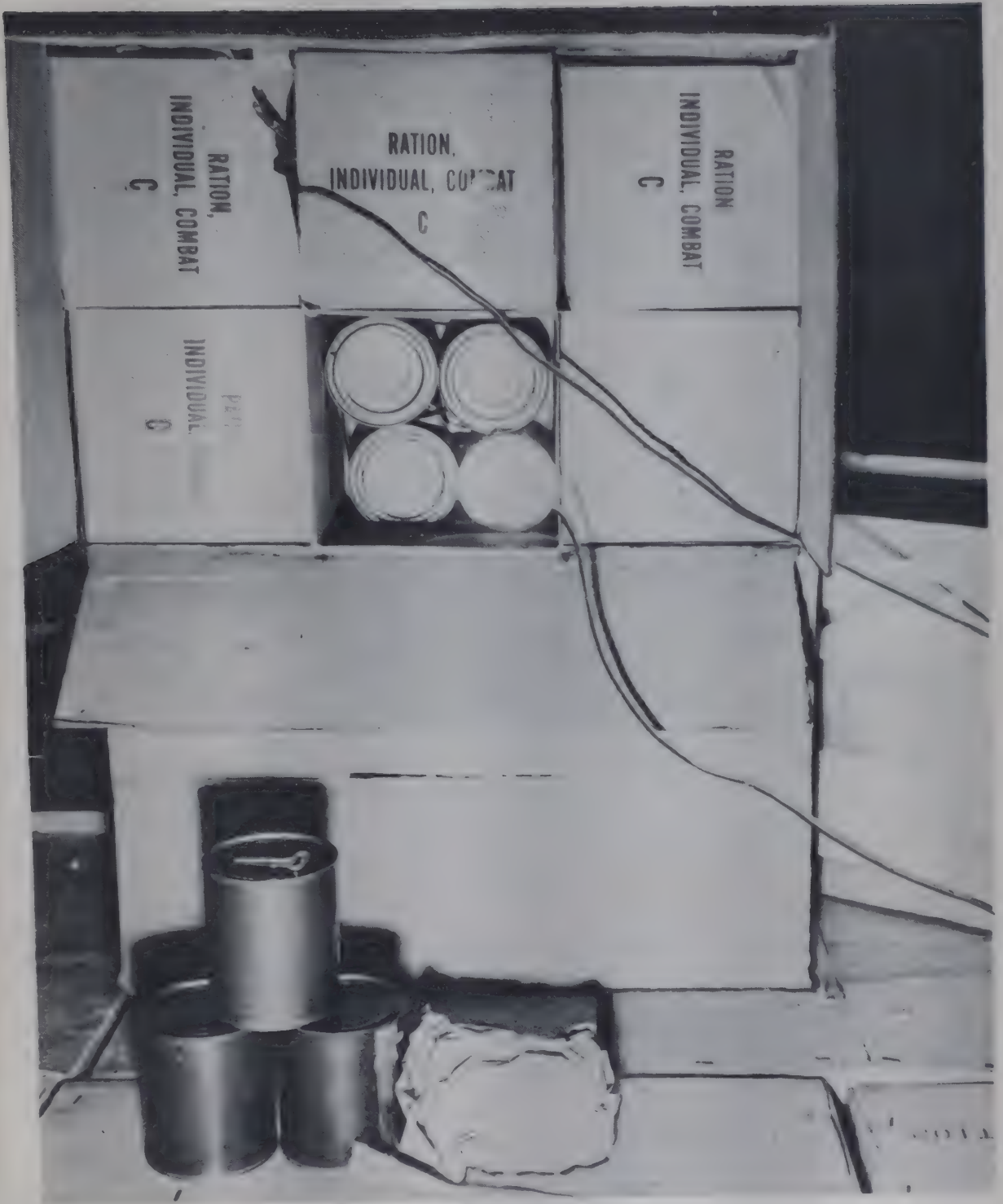


Figure 19.

recorded by a thermocouple inserted with bushings into the center of the can by the American Can Co., the can being restored to vacuum. For the most critical position (I), the luncheon meat was located in the top layer of four cans in a C Ration package at a location nearest the edge of the package and the case. It was therefore covered by, and within an inch of, three covering layers: the thin fiberboard of the ration package, the corrugated board of the case, and, in addition, a V-board overseas sleeve slipped over the case. In the other cases tested, the test can was placed in the lower layer of cans and toward the center of the case within the package.

Ambient conditions were recorded at the U. S. Weather Bureau Station at the airport, approximately 1 mile west of the site, at the site itself, and at Yuma Test Station, 30 miles northeast, where radiation records are continuously maintained (fig. 20).



Figure 20.

Climatic summary for period. During the period of test, 15 April to 21 September 1953, temperatures were very slightly higher than normal for May through September. Table 1 gives values for summer 1953, as compared to normals for the period of record.

Table 1. Summary of ambient conditions

Period of Test: 15 Apr. to 14 Sept. 1953

	May through September 1953	Normals*
Absolute maximum temperature.....	114° F., 17 Aug.....	123° F., Sept.
Absolute minimum temperature.....	51° F., 1 May.....	39° F., May.
Mean maximum temperature.....	102.8° F.....	101.1° F.
Mean minimum temperature.....	72.1° F.....	70.2° F.
Mean temperature.....	87.3° F.....	85.6° F.
Mean wind speed.....	8.6 mph.....	9.1.
Maximum total daily radiation.....	849 langleys, 27 May.....	867.
Mean total daily radiation.....	706 langleys.....	721.

*Normals are based on a 70-year record for temperature, 3-year record for wind speed, and radiation observations of 1952.

Preliminary test results. Total evaluation of a test of this nature will be the result of careful tabulation of all of the pertinent values observed, the determination of significant differences and inclusive values. However, much that is of immediate interest to this conference is available through the somewhat cursory analysis possible since my return from Yuma.

To this end we have sought in the preliminary analysis to determine the following: (a) absolute extremes of temperature in the car and top case, (b) frequency of occurrence at all class intervals of maximum temperatures of air in the top case, (c) frequency and duration of occurrence at all class intervals of all temperatures of air in the top case, (d) mean temperature of the bulk of the load during the 2 critical months of August and September, and (e) effect of radiation shielding in reducing extremes of temperature of air in case.

Examination of critical days. To determine absolute extremes, 7 critical days have been selected—1 in May, 1 in June, 1 in July, 3 in August, and 1 in September (figs. 21 to 27). Significant data have been extracted in table 2. These days were selected on the basis of the highest maximum temperature at the roof position for the month chosen, with the exception of 2 days. The absolute maximum recorded at any point within the roof airspace or cartons in the cars was 152° F., 11 August. The lowest maximum occurring on any day at this point was 93° F., 30 April, during a dust storm. Absolute maximum in temperature of air in the case occurred on 15 August, 119° F., accompanied by a food temperature of 111° F. Lowest maximum in air temperature of the top case was 81° F. on 30 April, food temperature being 79° F. on this day.

Table 2. Summary of boxcar temperatures and ambient conditions on selected days
Yuma boxcar research

Position	Location	Max. Temp. ° F.	Min. Temp. ° F.	Mean Temp. ° F.	Range ° F.	Hrs. over 90° F.	Hrs. over 100° F.	Hrs. over 110° F.	Hrs. over 120° F.	Hrs. over 130° F.
6 May 1953										
VI	Roof air	138	65	102	73	11			5	
VII	Air over load	124								
	Free air	97		82						
Differential	(Max. VI—free air max.)	41								
IA	Center top carton air	98			22	8				
IC	Center top carton food	93				6				
II, III, IV, V	Buried load	82	73	76	9					

Table 2. Summary of boxcar temperatures and ambient conditions on selected days
Yuma boxcar research—Continued

Position	Location	Max. Temp. ° F.	Min. Temp. ° F.	Mean Temp. ° F.	Range ° F.	Hrs. over 90° F.	Hrs. over 100° F.	Hrs. over 110° F.	Hrs. over 120° F.	Hrs. over 130° F.
<i>20 June 1953</i>										
VI.....	Roof air.....	143					13			7
VII.....	Air over load.....	131								
	Free air.....	100		86						
	Differential.....	43								
IA.....	Center top carton air.....	110			28		9			
IC.....	Center top carton food.....	103					5			
II, III, IV, V.....	Buried load.....	89		85	7					
<i>10 July 1953</i>										
VI.....	Roof air.....	150								7
	Free air.....	107		97						
	Differential.....	43								
IA.....	Center top carton air.....	118			24		17	9		
IC.....	Center top carton food.....	112					21	6		
II, III, IV, V.....	Buried load.....	99		94	8					
<i>6 Aug. 1953</i>										
VI.....	Roof air.....	148								
	Free air.....	108		94						
	Differential.....	40								
IA.....	Center top carton air.....	116		104	25		14	7		
IC.....	Center top carton food.....	110					16			
II, III, IV, V.....	Buried load.....	101		95						
XIIA.....	Top northeast corner.....	108		101	14		16			
XIVA.....	Top south half.....	106		100	10		14			
XIIIA.....	Second layer.....	101		98	5					
<i>12 Aug. 1953</i>										
VI.....	Roof air.....	151					12			
	Free air.....	112		95						
	Differential.....	39								
IA.....	Center top carton air.....	118		106			17			
IC.....	Center top carton food.....	111					21			
II, III, IV, V.....	Buried load.....			97						
XIIA.....	Top northeast corner.....	111		105						
XIIIA.....	Second layer.....	105								
XIVA.....	Foil covered.....	102								
<i>9 Sept. 1953</i>										
VI.....	Roof air.....	147								
	Free air.....	106		94						
	Differential.....	41								
IA.....	Foil covered.....	102			6		10			
IC.....	Foil covered.....	101			4		10			
II, III, IV, V.....	Buried load.....	101		96						
XIIA.....	Top northeast corner air.....	105			10		14			
XIIC.....	Top northeast corner food.....	103								
XIVA.....	Top south half.....									
XIIIA.....	Second layer.....	100								

YUMA BOXCAR RESEARCH
BOXCAR TEMPERATURES AND AMBIENT CONDITIONS
6 MAY 1953

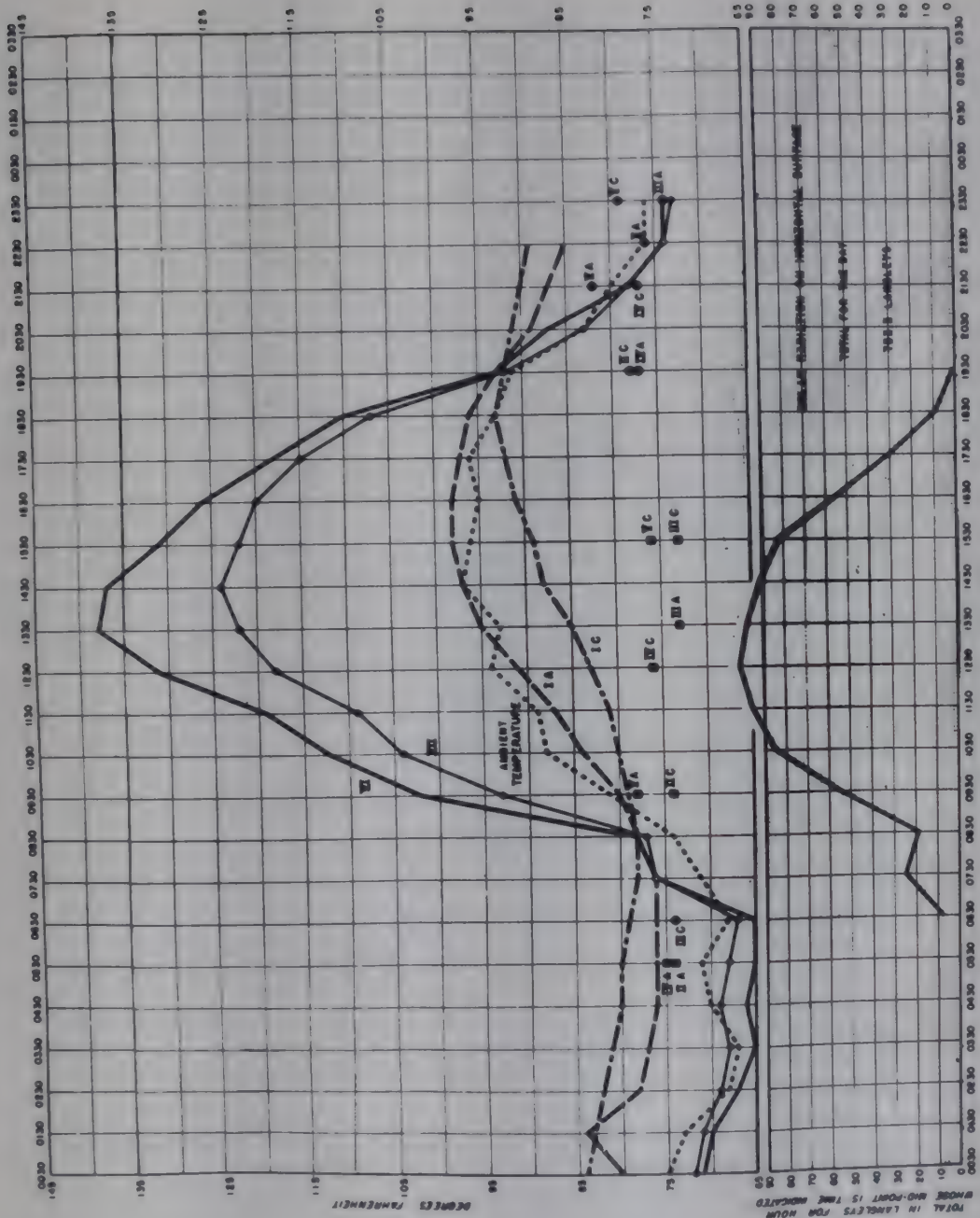


Figure 21.

YUMA BOXCAR RESEARCH BOXCAR TEMPERATURES AND AMBIENT CONDITIONS 20 JUNE 1953

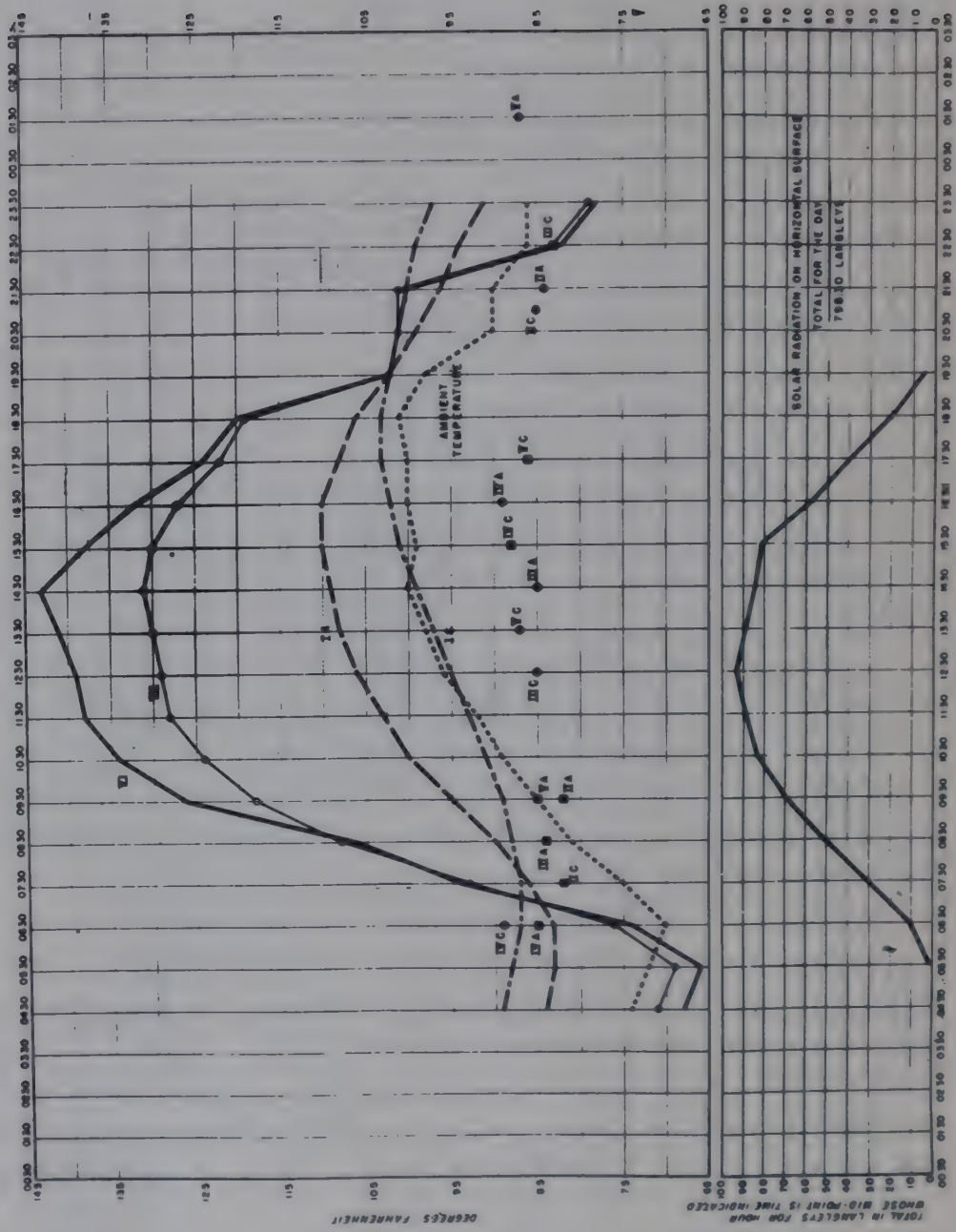


Figure 22.

YUMA BOXCAR RESEARCH BOXCAR TEMPERATURES AND AMBIENT CONDITIONS 10 JULY 1953

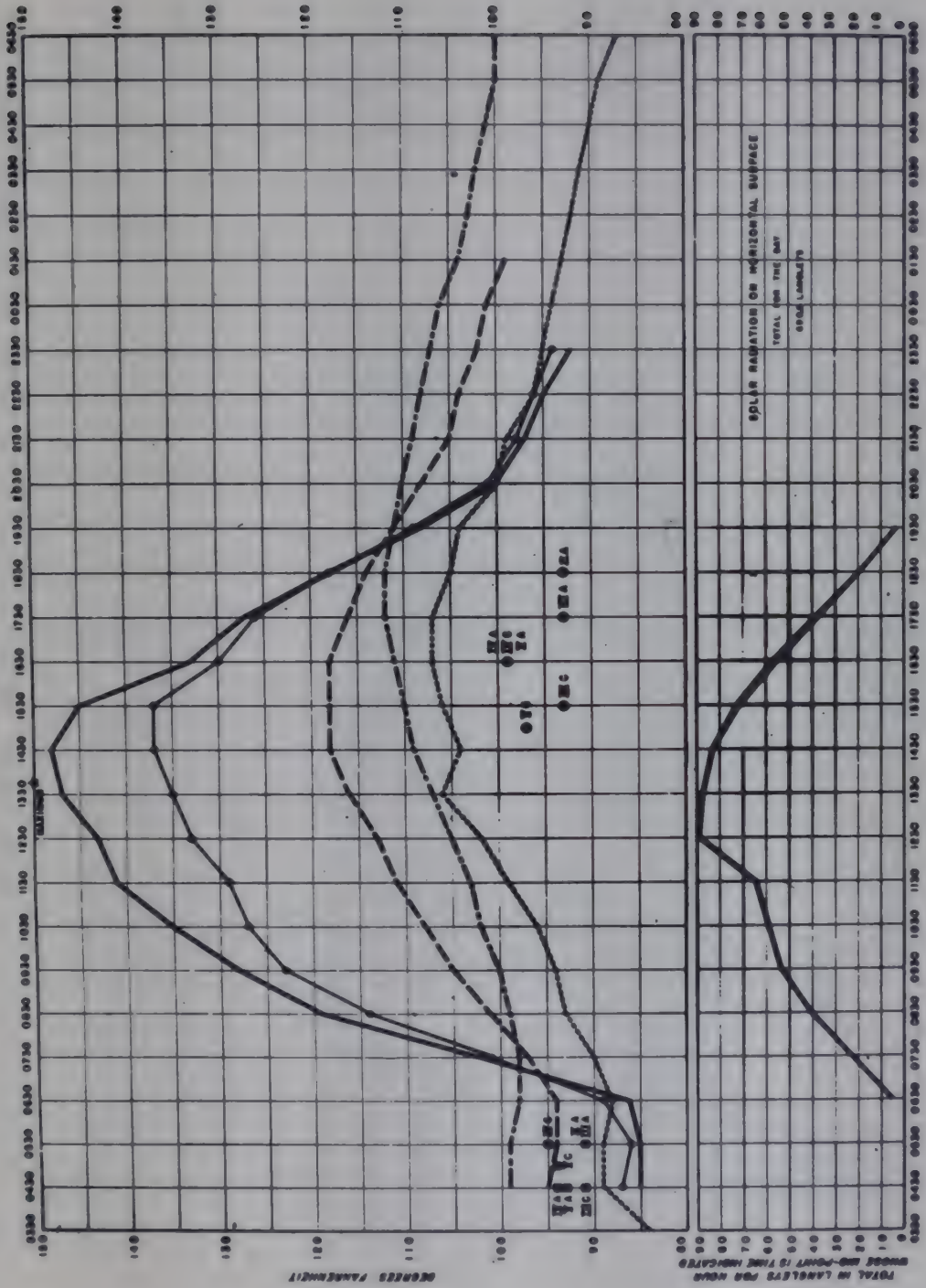


Figure 23.

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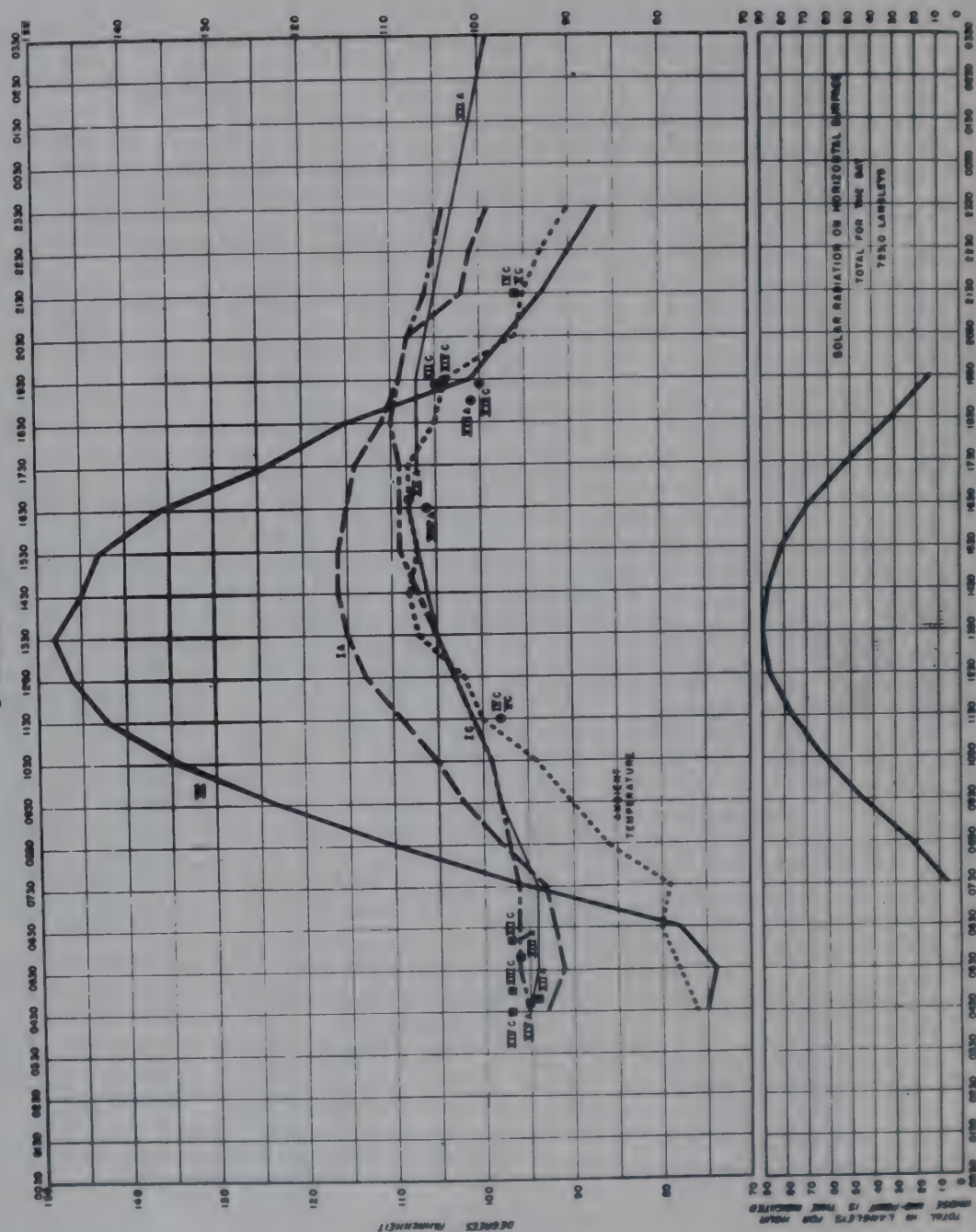


Figure 24.

YUMA BOXCAR RESEARCH

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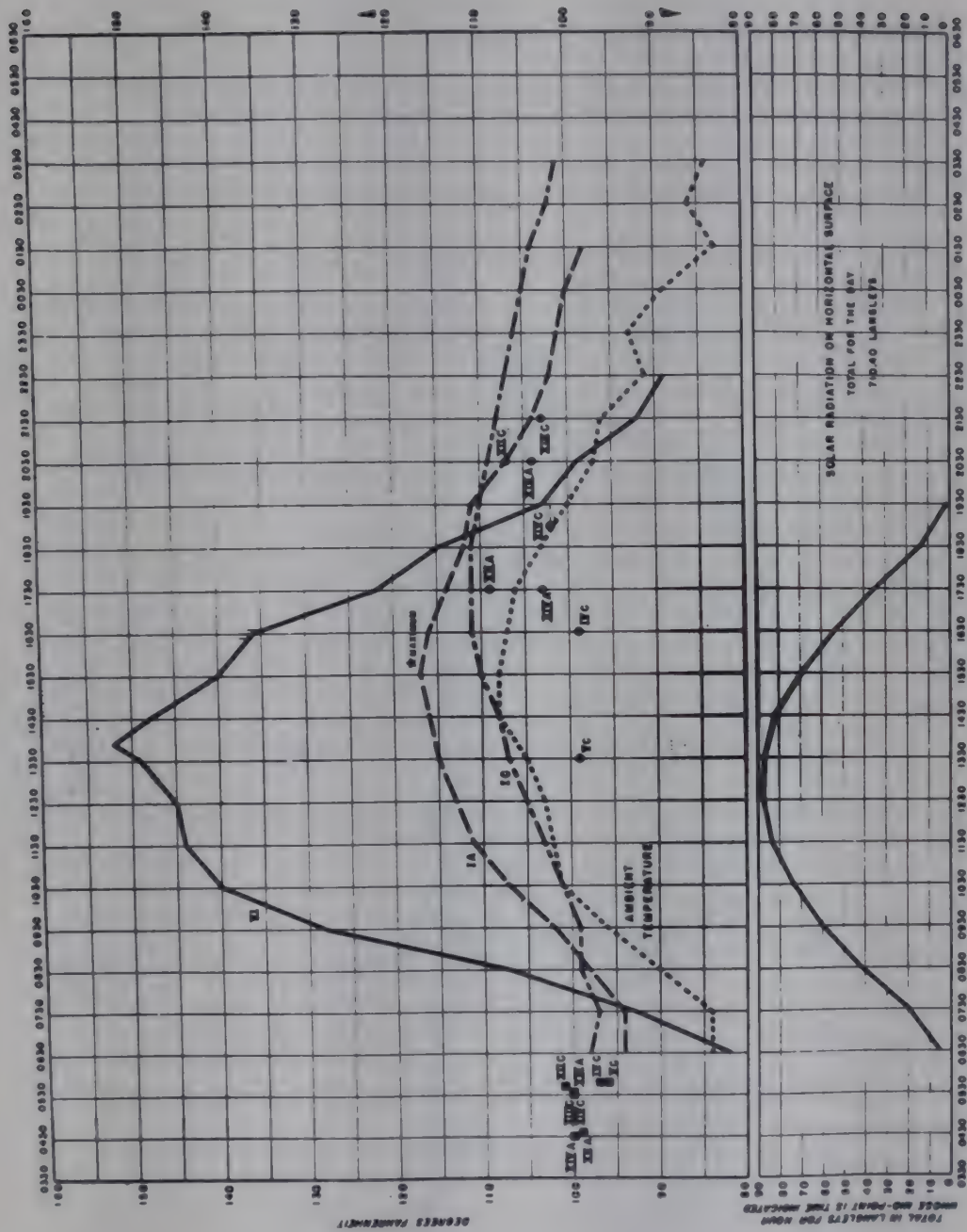


Figure 25.

12 AUG. 1953

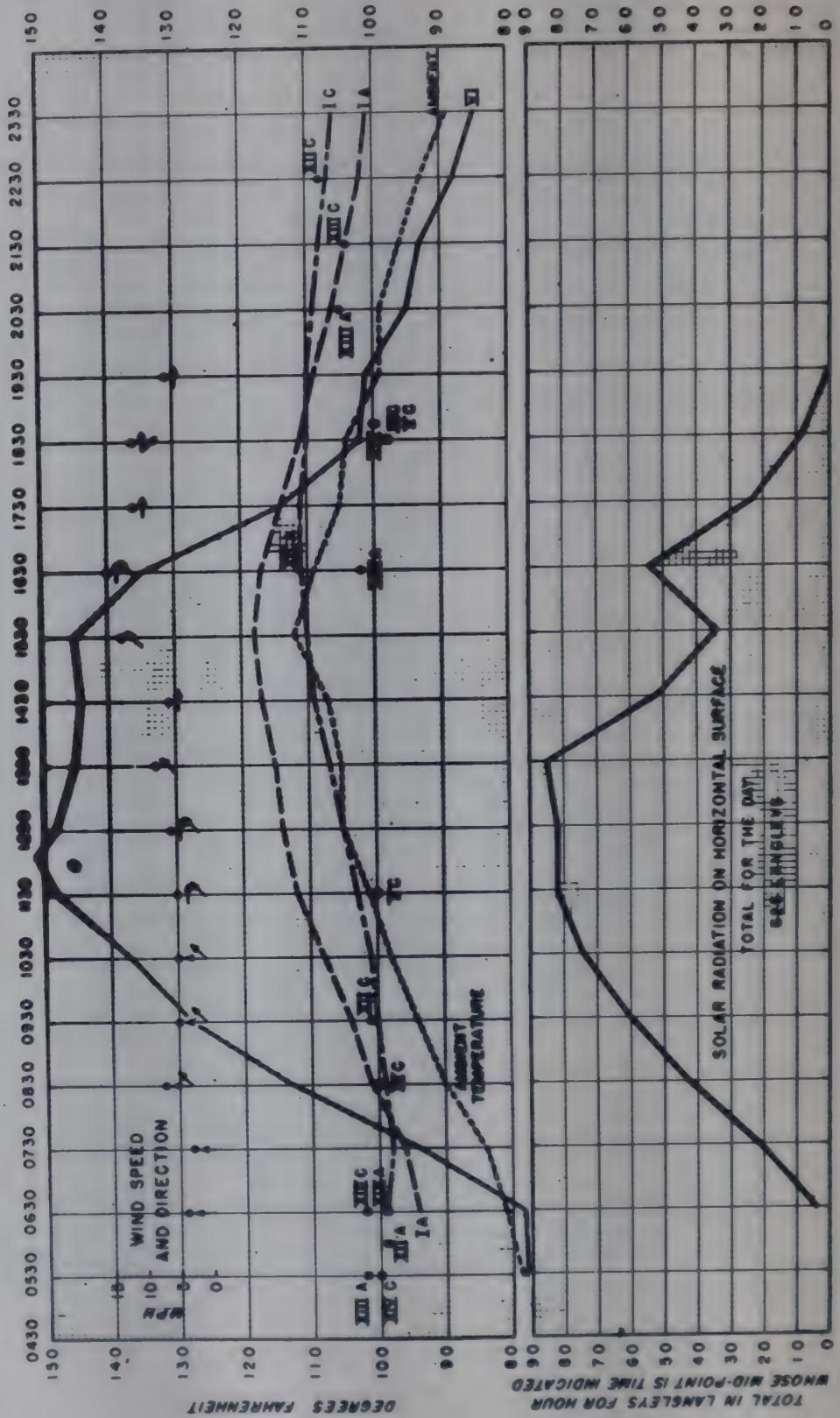
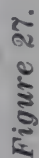


Figure 26.

73



Two of these critical days may now be examined in order to note the time progression and spatial distribution of temperatures at various points during the test period. Days selected are 12 August and 9 September.

Between the 11th and 15th of August, there occurred a series of days with ambient conditions favorable to extreme heat accumulation. On 12 August (fig. 26), aluminum foil had been spread over the south half of the car and Position XIV, the car having been exposed for 4 months.

One curve towers above those for the balance of the load. Curve VI, for a position 6 inches from the roof, reached 151° F. from a minimum of 76° F., ambient minimum being 77° F. The airspace in the car at night was often 3° to 4° F. below ambient minimum. Ambient maximum was 112° F., the differential of about 40° F. between roof air and ambient air being quite characteristic of maximum conditions with heat accumulation due to absorbed and re-radiated solar energy. Air temperature 6 inches over the load was not being measured this date, but would have attained about 138° F. The airspace then had a gradient of 13° F. in four-and-one-half feet. Air in the critical top center case reached 118° F. with a typical range of 24° F. Food temperature maximum in this case was 111° F. A spread of 5° to 7° F. at maximum between air in case and food is characteristic, as is the food temperature range of 13° to 15° F. The mean of all buried load positions (below top layer) for all readings during the day was 97° F., but temperature in no buried case exceeded 105° F., the maximum recorded at Position XIII A in the second layer. Ambient mean was 95° F., showing that the mass of the load, which had mean temperatures of about 75° F., 6° below ambient mean, at the start of the test, had experienced a real increase in mean temperature over ambient means and a slow, long-time heat gain. The aggregate range of readings in the buried positions is 6° to 9° F. as a rule, and individual range is much smaller, less than 4° F. Mean of air temperature in a buried case and food temperature in the same case is usually within 1 degree.

Roof air remained above 100° F. for 12 hours, and over 130° F. for 7 hours. Air in the most critical case remained over 100° F. for 17 hours and over 110° F. for 8 hours. Food in the same position remained over 100° F. for 21 hours and over 110° F. for 5 hours. As might be expected, roof-air temperatures, and to some extent top layer case-air temperatures, show an almost immediate response to changed ambient conditions, both hour-by-hour and day-by-day. On each of the critical days selected, mean roof-air temperature exceeded ambient mean by no less than 18° and no more than 20° F., although this relation cannot be considered statistically reliable as yet.

The balance of the buried load, on the other hand, required 2 months of exposure to reach a relatively steady relation with ambient means. On the days selected, from the middle of June to the middle of September, the mean of all buried load positions for all 24 readings during the day remained within 1° or 2° F. of ambient mean, slightly under in June and July and slightly over in August and September.

It will be noted that at Position XII, at the northeast corner of the car, away from the intense radiation from the steel doors, maxima in air in case are 7° to 10° F. lower than in the critical top center case. Ranges in both case-air and food temperatures are also reduced by about half, although duration of temperatures above 100° F. was about the same.

The foil spread over Position XIV reduced case-air temperatures 6° F. at positions away from the doors, by the valve-like action in reflecting incoming daytime roof radiation and radiating heat conducted up from the load with which it was in contact through a dark undersurface.

This radiation shielding was most marked on the 9th of September (fig. 27), the most critical day in that month. Foil had been placed over the critical top center case for 8 days. Roof air reached 147° F., within 5° F. of absolute maximum. However, maximum case-air temperature at the top center position was 102° F., food temperature maximum being 101° F. Both food and air remained substantially at or above 100° F. for 10 readings, but the range at this position was reduced to one-quarter of its value when exposed without radiation shielding. Comparing the values for this day with those of 6 August, which is justified on the basis of temperature at several control positions, we may assume that this position would have reached 115° F. unshielded. A reduction of 10° to 12° F. in case-air temperature and from 6° to 8° F. in food temperature may be conservatively ascribed to the foil shielding. Stated in another way, the presumption is that *on the most critical day of the summer, the case air would have been kept to 108° F. and the food to 106° F. as a maximum.* The duration of case-air temperatures above 100° F. would not, however, be so drastically reduced, since even on this day when other top layer temperatures were 6° F. below extreme values, 10 hours showed readings over 100° F. at the position under the foil. The protection is more a truncation of the maximum than a general downward shift of the whole cycle. Also, the reduction cannot be considered a constant for varying maxima of air temperature in the unshielded case, nor for positions away from the doors.

Frequency and duration of critical temperatures in the top layer. The second objective of this preliminary analysis, after the analysis

of days of most extreme heat accumulation in each month, was the determination of the frequency of occurrence of various classes of daily maximum temperatures of air in the top case, for the period 15 April to 1 September.

The range of these maxima is from 81° F. to 119° F., but values below 90° F. are very typical, occurring on cloudy or very windy or cool days in April.

For the whole summer, including 124 days or 4 months (since the September values when the position was foil-covered are not comparable and there were 15 missing days in June), table 3 will illustrate the distribution of maxima.

Table 3. Percentage frequency of daily maximum temperatures in air in top center case

Period of Test: 124 Days

	80-83	84-87	88-91	92-95	96-99	100-103	104-107	108-111	112-115	116-119
Percent of all days in period	0. 8	8. 1	9. 7	8. 9	12. 1	6. 4	8. 1	14. 5	20. 1	11. 3
Cumulative percent of all days in period when value of max. temp. was equal to or above lowest figure of class interval	100. 0	99. 2	91. 1	81. 4	72. 5	60. 4	54. 0	45. 9	31. 4	11. 3

When daily maximum temperature in air in the top center case is above 90° F., the range and form of the daily temperature cycle is quite uniform; therefore, it is possible to make a rather accurate estimate of duration of temperature for a given temperature interval both for a given day and for the entire test period, without actual analysis

Table 4. Duration of top center case-air temperature at or below maximum by amount indicated during diurnal cycle

Degrees below Maximum	Duration in Hours Below Maximum By No More Than Amount in Column 1	Class Interval Degrees Below Maximum	Duration at Each Class Interval	Percent of Day	Cumulative Percent of Day During Which Temperature Was No More Than Highest Figure of Class Interval Below Maximum
4	6	0-4	6	25. 0	25. 0
8	9	8-5	3	12. 5	37. 5
12	11	12-9	2	8. 0	45. 5
16	14	16-13	3	12. 5	58. 0
20	19	20-17	5	21. 0	79. 0
24	24	24-21	5	21. 0	100. 0

of each hour in the entire record. Thus, for any given day where maximum is above 90° F., the duration of temperature is given by table 4, where number of hourly readings is taken as equal to duration in hours.

By combining the last column of table 4, and the frequency distribution given in table 3, we obtain a good approximation of duration of all temperatures in the top center case as shown in table 5, using class intervals based on the midpoint of the class intervals of table 3.

Table 5. Duration of temperature in air in top center at values indicated

Entire Test Period: 124 Days

Class interval	65.5 to 69.4	69.5 to 73.4	73.5 to 77.4	77.5 to 81.4	81.5 to 85.4	85.5 to 89.4	89.5 to 93.4	93.5 to 97.4	97.5 to 101.4	101.5 to 105.4	105.5 to 109.4	109.5 to 113.4	113.5 to 119.0*
Percent of total test period.....	2.0	6.5	7.6	7.6	8.9	10.2	12.5	13.0	8.6	6.8	7.0	6.5	2.8
Cumulative percent of total test period during which temp. was equal or above lowest figure of class interval.	100.0	98.0	91.5	83.9	76.3	67.4	57.2	44.7	31.7	23.1	16.3	9.3	2.8

*It will be noted that because of the use of the midpoint of the class interval from table 3 as a basis for the classes of table 5, the last class must be larger to accommodate the absolute maxima. Its percentage is slightly too small.

A similar method of approximation may be applied to the week of 13 to 19 August, the most critical week of the test. Maxima clustered very closely around 117° F.; so the hours of this week can be apportioned by using the mean maximum of 117° F. as a base, to yield table 6.

Table 6. Duration of temperature in air in top center case at values indicated

Period: Week of 13 August to 19 August inclusive

Class interval	93-96	97-100	101-104	105-108	109-112	113-119*
Hours temp. was equal to or above lowest figure of class interval.....	168	133	98	77	63	42
Cumulative percentage of period in which temp. was equal to or above lowest figure of class interval.....	100.0	79.0	58.0	45.5	37.5	25.0

*See note, table 5. In table 6, an average of daily maxima clustered within one or two degrees was used as the base figure, and for this reason the last class is larger and its percentage slightly too small.

For the 3-week period of 1 to 21 August, a similar table was prepared, table 7, using the frequency distribution of maxima and the percentages of table 4.

Table 7. *Duration of temperature in air in top center case at values indicated*

Period: 1 to 21 August

Class interval	85.5 to 89.4	89.5 to 93.4	93.5 to 97.4	97.5 to 101.4	101.5 to 105.4	105.5 to 109.4	109.5 to 113.4	113.5 to 119.0
Cumulative percentage of period in which temp. was equal to or above lowest figure of class interval-----	99. 9	96. 9	83. 9	64. 1	49. 1	38. 7	26. 2	9. 5

Temperature regime of the buried load. The maximum and mean temperature attained anywhere within the buried load for each selected critical day is shown in table 8.

Table 8. *Maximum and mean temperature reached in buried load on selected days*

	6 May	20 June	10 July	6 Aug.	11 Aug.	12 Aug.	9 Sept.
Maximum temperature within buried load-----	82	89	99	101	104	105	101
Free-air max. temp.-----	97	100	107	108	110	112	106
Mean temperature for all readings at all positions in buried load-----	76	85	94	95	96	97	96
Free-air mean temperature---	82	86	97	94	96	95	94

Tentative conclusions from the Yuma research. It may be concluded from the discussion above that under carefully selected conditions conducive to extreme heat accumulation in a boxcar with typical load of Quartermaster subsistence items, where temperature is measured at points in the load comparable to oven exposure, the following conditions existed:

1. Absolute maximum reached in the air near the roof was in this test 152° F. Absolute maximum in the air in the most critical case was 119° F., diurnal range at this position for most test days being about 24° F. Food in this case reached an absolute maximum of 112° F., the differential of 6° to 7° F. from case-air maximum being quite constant in amount.

2. On 11 percent of the days of the test, maxima in top center case air were 116° F. or over, within 4° F. of absolute maximum. Sixty percent of the days had case-air maxima equal to or over 100° F.; 39 percent had maxima equal to or over 110° F. During the most critical week of the period, about 63 percent of all the readings (24

per day) were equal or over 100° F. and 34 percent were equal or over 110° F. For the whole period of the test, about 26 percent of all the readings were equal or over 100° F. and about 8 percent were equal or over 110° F., all of the above values applying to top center case air.

3. The load was not uniform in temperature behavior, but may best be considered as divided into two portions: (a) the top layer, especially that between the steel doors, and (b) the main body of the buried load. In the top layer of the load, cyclical temperature behavior was closely related to the diurnal cycle of solar radiation and ambient temperature. Ranges in case-air temperature were about 24° F. Parts of the case-air temperature cycle during each day in this layer were markedly below the temperature of the balance of the buried load and other parts markedly above it; the mean on critical days was about 9° above the buried load mean.

In contrast, the main body of the load, as might be expected, remained very conservative with respect to the daily cycle of temperature. Its behavior may best be studied by sampling representative or critical days during each month, and by considering the gross mean of air temperatures in all buried cases for all hourly readings, since the aggregate range of all temperatures in all cases buried within the load was usually about 10° F., and the individual case range was only 2° to 4° F. The great preponderance of the load, then, clustered closely within 5° or 6° of gross mean buried load temperature which climbed slowly with little cyclical fluctuation during the test period. For the months of August and September, large portions of the load remained a few degrees above or below 100° F.

4. Finally, it has been demonstrated that maximum temperatures in air in the critical top center case may be reduced 10° to 12° F. on critical days by the use of aluminum foil shielding laid on the cases, food temperature being reduced 6° to 8° F. It can be concluded as a corollary that on the most critical days experienced, case-air temperature at the most critical location would not have exceeded 108° F. and food 106° F. At locations away from the central door position, temperatures could have been kept below 105° F. in case-air and food.

Cameron Station research. The test at Cameron Station may be dismissed for our purposes here by the simple statement that maximum temperature experienced in boxcar air was 147° F. and maximum case-air temperature was 103° F. It is interesting to note that the roof-air temperature reached a level within 5° F. of that at Yuma, but that case-air maximum temperature was 15° F. below that at Yuma.

Limitations of present research. The research as carried out has several limitations, of which the most important are mentioned:

1. It was necessary to select a typical load, since it could not be assumed that further research of this type would be carried out. It is quite possible that higher top-layer and buried-load temperatures would be attained in a load whose components had greater absorptivity, conductivity, and a lower specific heat than that chosen.

2. The car was not loaded to maximum capacity, since such a load is quite unusual. In a maximum capacity load, the top-layer cases would be nearer the roof. Radiation load from the roof would not be markedly increased, since the solid angle subtended would not be greatly increased, but the top-layer cases would presumably be in contact with hotter air. However, the thermal mass of the load would also be greater, and would tend to absorb radiation and greater convected heat without large temperature increases.

3. As noted under climatic factors above, sites in Death Valley, Iran, or the Sahara would have conditions favoring slightly greater heat stress. Indeed, other summers at Yuma have exceeded that of 1953 in both ambient temperature and radiation load.

4. The car was not oriented true north and south. Such an orientation plus a ground surface of black asphalt and shelter from prevailing winds might slightly increase maxima.

Recommendations

It is felt that any recommendations as to food-temperature testing must await an answer to the question posed at the beginning of this paper. Are subsistence items to be designed to withstand temperature testing at less than observed extremes, entailing a calculated risk? In this connection, it should be recalled that the Yuma boxcar research was not conducted at the locations of the most extreme known heat stress. Also, temperature maxima reached in case-air were 70° F. below those reported from the Blythe research, and 6° F. below those from Indian Bay, Saipan, and Peliliu, although all these maxima were reported from stacks tightly covered with tarpaulins.

Recommendations also must await definite knowledge of storage and shipping practices in areas of heat stress, especially in dump storage. In the case of the boxcar, the value of single-faced foil has been shown, even where spread only in the central third of the car. In dump storage, recommended practices are common knowledge. They include: (a) use of uncovered dumps or of the raised tarpaulin, preferably with reflecting surface, (b) loose, open stacking in stacks of large mass, (c) orientation of stacks at 45° F. to the cardinal points of the compass, (d) use of cleats to separate layers where possible, and possibly (e) reflecting surfaces for cases.

The requirements of hot-wet climates and of camouflage necessitate modification of some of the above practices. Where they can be

depended upon, however, it is suggested that peak case-air temperatures of 115° F. and sustained case-air temperatures of 110° F. might be discussed as upper limits for temperature testing.

Where such practices do not obtain, however, it is suggested that a peak case-air temperature of 125° F. and a 4-hour sustained case-air temperature of 120° F. be discussed.

It would be of interest at this time to hear a comment on extent of deterioration experienced in the field in the use of the present 100° F. limit.

CHAIRMAN TRESSLER:

We will hear next from Mr. Wilbur Pentzer, Agricultural Marketing Service, USDA, who will discuss some of the changes which occur in dried fruits and indicate the advantages of the cool or cold storage of dried fruit.

Dried and Dehydrated Fruits Are Semiperishable

WILBUR PENTZER

Agricultural Marketing Service, United States Department of Agriculture

A sizable portion of the nation's fruit crop is converted into dried fruits, including about half of the grapes produced, most of the prune and fig crops, all of the dates, and a smaller portion of the peach, apricot, and apple crops. A total production of 600,000 tons of dried fruit is not unusual in a good year. Raisins are the most important dried fruit, with a production of about 310,000 tons; prunes are next with about 160,000 tons; then figs with 35,000 tons; peaches and apricots with approximately 25,000 tons; and apples, dates, and pears are considerably less. Fruits are dried over a relatively short season from about July to October and must be stored in some fashion until marketed. The general practice in handling and storing dried fruits is to treat them as nonperishable commodities as long as they are in the original dried state or natural condition. As an example, after grapes are dried to raisins they are put into sweat boxes of about 150-pound capacity and stored in open sheds or in large stacks with improvised roofs of galvanized metal until needed for packaging. Other fruits after drying are stored either in bins or in burlap sacks in farm buildings or warehouses. The fruit is held in this way throughout the fall and winter months at variable temperatures and humidities. Insect control, when practiced, is obtained by fumigation.

Before the fruit is marketed, it is cleaned, graded, and packed, and moisture is added by the washing and steaming process it goes through, thus making the fruit more perishable. The fruit now requires lower storage temperatures and humidities to keep it from spoiling.

Cold storage estimates indicate that during summer months there may be as much as 60,000 tons of dried fruit in storage. This would represent about 10 percent of the total production. Cold storage is more generally practiced for cut fruits such as apples, pears, apricots, and peaches than it is for the other types of dried fruits such as raisins, prunes, and figs.

Experimental Work

A considerable amount of work has been done that indicates dried fruit is benefited by cold storage temperatures. Nichols and Reed in 1931 (2) found that the darkening of apricots, peaches, and pears took place about twice as fast at 75° F. as it did at 32° F. Stadtman, Barker, Haas, and Mrak (3) working with dried apricots found that high temperatures in the range of 72° to 120° F. brought about darkening, and the rate of darkening was increased about four times for every 18° F. rise in temperature above 72° F. The deterioration of dried fruit as affected by temperature and humidity was studied for a number of years at the Fresno Laboratory of the U. S. Department of Agriculture (1). Gravenstein apples, Blenheim apricots, Adriatic figs, Muir peaches, Thompson seedless raisins, Bartlett pears, and French prunes were included in these tests. Storage temperatures of 32°, 40°, 55°, 75°, and 90° F. were compared. At the two lower temperatures, humidities of 55 percent and 80 percent were employed, and, at the higher temperatures, the humidity was maintained at 65 to 80 percent at 55° F., 35 to 50 percent at 75° F., and 50 to 60 percent at 90° F. The fruit was stored after processing and packed in commercial containers holding 25 or 30 pounds. In addition, box liners of moistureproofed paper, pliofilm, cellophane, and cellulose acetate were employed. The Army arsenal case was also tried because of its moistureproof qualities. The fruit was inspected periodically for color, texture, flavor, mold, and sugaring during a storage period of a year or more. The moisture content of the fruit was followed through storage, and sulphur dioxide, ascorbic acid, and carotene were determined on those fruits in which these constituents were of any importance.

Studies on the tolerance of dried fruit insects to cold storage temperatures were made in cooperation with the Bureau of Entomology and Plant Quarantine.

Deterioration of Dried Fruit in Storage

Browning. The development of a brown color in certain dried fruits proved to be a good indication of old age. It is well known that the brown color that develops is the result of a browning reaction that occurs in many kinds of food products. Browning was seri-

ous in apples, apricots, pears, and peaches and also appeared to some extent in figs and prunes. It was caused by too high storage temperatures. At 32° F., the original color of the fruits was retained for 15 months and almost as long at 40° F. Some browning took place in 5 months storage at 55° F. and usually in only 3 months or less at 75° and 90° F. Storage humidity had practically no effect on browning. We found that depletion of sulphur dioxide in storage was directly related to the development of brown color in cut fruits. Our results agree with those of Stadtman (4) *et al.*, in that the percentage of the original amount of sulphur dioxide lost was a better indication of susceptibility to browning rather than the actual amount of sulphur dioxide left in the tissue. Most of the cut fruits darken when they have lost 75 percent or more of the original sulphur dioxide content.

Sugaring. Raisins, figs, and prunes were susceptible to the development of sugar crystals on the surface or within the flesh of the fruit. Sugaring detracts from the appearance of the fruit and would certainly affect its salability. Sugar crystals that form under the skin of prunes are usually referred to as "red" sugar to distinguish them from the white powdery sugar that develops on the surface of prunes. Sugaring of raisins produces an objectionable granular texture to the flesh. The main cause of sugaring in dried fruit in storage is high humidity. For this reason 55 percent humidity or lower was necessary at both 32° and 40° F. to control sugaring of susceptible fruit such as raisins, figs, and prunes. At humidities higher than 55 percent at 32° or 40° F., the storage life was limited to 4 months or less because of sugaring. Fruit with low moisture content when stored was less susceptible to sugaring than fruit with higher water content.

Mold. The moisture content of the fruit is the critical factor for mold development. Fruits after completing the original drying process are low in moisture, and, unless they absorb moisture in humid storage, mold makes little headway. After the fruit is processed and its moisture content increased, the fungi causing mold have a much better chance to grow. Some of the cut fruits, such as dried apples, may be 22 to 23 percent moisture after they are processed and close to the level at which mold will develop. In a moist storage atmosphere, the outer fruit will pick up enough moisture to enable mold to get started. The best protection in our storage experiments against mold development was low humidity and storage temperature, preferably 32° F. We found that the humidity should not be higher than about 55 percent. Mold developed rapidly on some fruit held at 55° F. when the humidity approached 80 to 85 percent for several weeks. On the other hand, some fruit molded even at temperatures as low as 40° F. in 80 percent humidity. The fruit next to the outside of

the package where moisture take-up was the greatest was first affected. All of the cut fruits are treated with sulphur dioxide to preserve color and to prevent mold growth. We found that low storage temperatures help to retain sulphur dioxide, whereas it was soon lost at 75° and 90° F.

Changes in flavor. It was rather surprising to find that high temperatures brought about a change in flavor of some fruits, such as raisins and prunes. Raisins developed a caramel-like flavor and prunes became somewhat insipid and flat in taste at 75° and 90° F. as compared with similar samples held at 32° and 40° F.

Loss of ascorbic acid and carotene. Ascorbic acid was found in fair quantities in some of the dried fruits tested, notably dried peaches. One lot averaged about 21 mg. per 100 g. Best retention of ascorbic acid was obtained at 32° and 40° F., and poorest retention at 75° F. Tests were not made at 90° F. Carotene, or provitamin A, was present in apricots in fairly large amounts ranging from 3,000 to 6,000 mcg. per 100 g. Storage temperatures of 32° F. retained 90 percent or more of the carotene for 12 months, whereas, at 55° F. only about 50 percent was left at this time.

Insect damage. Insect damage can be the most serious of all the factors that bring about deterioration of dried fruit in storage. Cold tolerance studies on raisin moth, Indian meal moth, sawtooth grain beetle, and the dried fruit beetle, all important dried fruit insects, showed that a temperature of 0° F. killed all stages of the insects in a few hours, but long exposure of 6 months or more was required at 32° F. to get a complete kill of cold resistant stages of certain insects, such as raisin moth larvae. Temperatures of 32°, 40°, and 48° F. gave effective control of insect damage, for all of the insects mentioned were inactive at these temperatures, but substantial killing occurred only at 32° F. or colder.

Effect of liners and packaging. It is of interest to note that none of the moisture-resistant liners or the waterproofed arsenal case tried for storage of dried fruits were successful in preventing darkening or sugaring. As indicated, darkening is primarily a function of temperature. Sugaring will eventually take place in susceptible fruits, such as raisins, prunes, and figs, even though they are held at their original moisture content. Therefore, a moistureproof package or liner would not be expected to be of any benefit except to prevent the absorption of additional moisture and hasten the sugaring process.

Storage Recommendations

All of the cut fruits which included apples, pears, peaches, and apricots, retained best quality when stored at 32° F. and 55 percent relative humidity. This was true for even short storage periods of 4 or 5 months. A temperature of 40° F. was almost as beneficial as 32°

F. At 40° F. a humidity of 80 percent caused dried apples to gain moisture, become dark, and eventually become moldy, whereas, at 32° F. this humidity was not so harmful. In the case of cut fruits, darkening and mold development are the two important considerations, and the lower the temperature the better control we have of these processes of deterioration.

A temperature of 32° or 40° F. was necessary to prevent darkening of figs, and low humidity of about 55 percent was required to prevent objectionable sugaring. Prunes were also susceptible to sugaring and loss of flavor in storage. The best protection against sugaring of prunes in storage was a humidity low enough to cause some loss of moisture, and 55 percent humidity at both 32° and 40° F. accomplished this. No sugaring was observed in 15 months at 55 percent humidity at either of these temperatures, whereas, slight sugaring took place in 10 months in 80 percent humidity at both of these temperatures. A temperature of 55° F. held prunes in good condition for 5 months, but longer storage at this temperature favored mold and sugaring. Raisins, like dried figs and prunes, were very susceptible to sugaring in storage, especially if they were not held at low humidities. A humidity of 55 percent was required at 32° and 40° F. for storage even as short as 4 months. Although sugaring and mold could be controlled at 75° and 90° F. by low humidity, the raisins developed poor texture, flat flavor, and dull appearance at these high temperatures. Raisins were extremely susceptible to storage room humidity and gained or lost moisture rather readily, depending on the humidity of the surrounding air. Our general conclusions were that humidity control was probably of more importance with raisins than with any of the other dried fruits if we were to prevent sugaring and mold.

If we were to select just 1 storage temperature and humidity for the storage of dried fruit, we would recommend 32° F. and 55 percent humidity. All the fruits remained in good to excellent condition for 15 months under these conditions, with the exception of raisins, which in 1 year showed slight sugaring of fruit on the outside of the package.

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Discussion

MAJOR J. C. WILSON (Quartermaster Food and Container Institute) :

In the talks presented by the various speakers, and primarily in Mr. Porter's talk, the figures of minus 10° F. and 100° F. as minimum and maximum temperatures were given. Can we take those figures as arbitrary, and, if so, who has authorized them? The thought has occurred to me that in the low end of the scale, in a place like Alaska or Fort Churchill, Canada, you will get temperatures under tarp storage of perhaps minus 40° or 45° F., followed by a seasonal fluctuation up to about 80° F., which might be a thing to consider. On the other hand, I think in hot sections of the United States—places like Florida, Texas, Arizona, and California—you will get, under tarp, temperatures of more than 100° F. Even in places like Ottawa and Toronto, Canada, where it is considerably cooler normally than in the U. S., you can expect such temperatures. From the standpoint of risk of losing some of the items in storage, can't we take those figures as pretty much as arbitrary now and use them as a policy scale?

CHAIRMAN TRESSLER :

I believe minus 10° F. was selected first because that was a temperature that Dr. Woodroof could obtain in his laboratory storage, and, second, it was more or less believed that if a ration were held at minus 10° F. there would be no marked changes. It was a type of control whereby one could note what happened when the ration was subjected to 70° and 100° F. storage.

WILSON :

I presume that this is perhaps a policy decision that someone cannot make at this meeting, but we are interested from a Canadian standpoint, because I have been asked the following question from Canada: How are these temperatures determined? Did someone just pick the figures out of the air and say that one would do as the minimum and the other would suit as the maximum, or are they the sum total of everyone's opinion?

D. H. MILLER (QM R&D Command) :

With reference to the low temperature side, the minus 10° F. was probably adopted, as Dr. Tressler suggested, as a matter of testing convenience. The standard regulation on temperature specified minus 80° F. for storage, which is much too conservative, and we are now in the process of recommending that it be modified to minus 65° F. Incidentally, the same factor that enters in any storage condition enters here. When you store material, you store heat; you store thermal inertia. So the storage never gets as hot or as cold as the air. With respect to air temperatures, I am continually required to educate people as to how to use air temperatures. Air temperature is irrelevant in most cases. You are interested in food tem-

peratures. Sometimes you can get one from the other. Sometimes the relationship is not very close. At the time of low temperature, if you have any considerable body of storage, the heat coming out of the storage will take care of the heat losses and maintain the temperature at a much higher level than minus 80° F.

G. B. NUTT (Office of The Quartermaster General) :

That is something we are also going to get into—160° F. is probably too high. I cannot conceive of any possible situation where you would get 160° F.—short of using a blowtorch. Where we had a small mass with no ventilation, with tight tarpaulin, the results of three tests indicated a temperature of around 125° F. to be the more realistic maximum.

WILSON :

It seems that the practical thing to do on the matter is to take a figure like 100° F. and allow for the majority of cases in that range. Take 100° F. as the maximum, and forget about the other 25 percent or less that constitute a minor category.

MILLER :

Your experience seems to indicate that a maximum of 120° F. is a conservative upper limit.

WILSON :

I would like to see a policy decision or expression of opinion that minus 10° F. and 100° F. are the figures to take.

CHAIRMAN TRESSLER :

Colonel Kujawski, would you want to comment? I think you had something to do with suggesting, originally, the 100° F. for 6 months.

COLONEL J. S. KUJAWSKI :

Some 12 years ago I had some personal experience with respect to the establishment of maximum and minimum temperatures. I got somewhat rabid on the subject 5 years ago when asked the question: Just how was the 6 months at 100° F. established? Some of the studies reported today were the result. What the final answer will be, frankly, I don't know, and I don't think anybody in this room can say at this time. However, it does occur to me that perhaps we should not only be making the studies from a laboratory point of view, but also develop data in the field—to find out exactly what the field is encountering in shipping from the manufacturer to the point of consumption by the soldier. Factors involved are (a) question of time involved, (b) location, and (c) certainly climatic conditions with the subsequent temperatures.

I think the air temperature is of lesser interest than the food temperature. From the standpoint of food service, I would like to think that the food would be cooked in the range, but all too often I am afraid it is cooked before it reaches the stove.

One other point I would like to make, before I leave the matter of maximum and minimum, is the long term nature of the problem. The progress made to date has been good. It presents a problem to the technologists as well as to the Military, and although work is under-way, a lot more work is necessary in this field.

One other point, I am just a little disturbed about this so-called distinction of perishable subsistence and semiperishable subsistence. I wonder if someone would be good enough to tell me at what point there is a distinction somewhat more clearly than has been done this afternoon. As a military man, I have always liked to construe all perishable subsistence as perishable under the strict definition of Webster. I think perhaps even at this level here in Washington one perhaps may be led in some channels, as we do today, to consider our subsistence operations in two general categories—one perishable and the other nonperishable (thinking primarily of canned goods). Now, with this new or revised concept of semiperishable, I wonder if someone here can locate for me the cutoff point. We probably have 300 to 500 subsistence items. Which are in the category of perishable and which semiperishable?

CHAIRMAN TRESSLER:

I was hoping Dr. Goresline would answer that, but I think the answer is fairly clear—that they are all semiperishable with the possible exception of salt. Even sugar possibly deteriorates slowly.

KUJAWSKI:

There is only one other that I know of, Dr. Tressler, and that is pepper. I understand pepper has a longevity before grinding.

CHAIRMAN TRESSLER:

Before grinding, but after grinding it is highly perishable.

DIEHL:

The work that Proctor did at MIT showed that.

KUJAWSKI:

We want to be sure we are speaking of specific items with respect to perishability and nonperishability. But I think what we are speaking of here are the items the Military are procuring. From our own standpoint, as you know, we consider all items in the category of perishable, because we have tried to get them in and out of the supply line within 2 years. Maybe that 2-year period should also be reinvestigated. I don't know how sound it is. With the studies made to date, you have here practically a whole new field for research; and, as such, the problem should be developed and spelled out very clearly before endeavoring to answer some of the more specific points.

CHAIRMAN TRESSLER:

Dr. Woodroof is starting the second year of a 5-year research program. We have been assured that we will have funds to carry on for

that period of time. I doubt if he will get all the answers in that time. I believe Dr. Mitchell thinks, so far as the Stability Division's work in this field is concerned, that they will still be studying it 25 years from now. In other words, we won't have the answers right away. But I do feel that what we now have indicates that canned goods and dehydrated foods should be considered as definitely perishable items and should not be held in common storage if the temperature of those products is going to rise above 90° F. in common storage.

KUJAWSKI:

I would like to make an unofficial comment, Mr. Porter, on calculated risk. I would like to cite an experience. At the height of the Korean conflict in 1950—Mr. Rubinate can testify to it—when I was at the Food and Container Institute, we were under terrific pressure to reduce packaging requirements for operational rations. It is an old story—in the Military you really don't get too much credit for what you do. It is the one thing you don't do that gets the attention. I said, "You tell us whether you want to assume a 1 percent loss or a 10 percent loss, or any point from 0.0 percent to 100 percent." We put that request down in writing. I never did get an answer to my inquiry. I don't think you will either. As you know, there are two things that must work in a time of operation. One is the ammunition the soldier carries, and the next is food, which is fuel for the soldier. I think for research and for practical aspects you won't get an answer to that calculated risk query, at least a specific answer, because it will be expected at all times that there will be adequate and satisfactory subsistence available for supply, if and when needed. Of course, that is unofficial, but it is still a very practical approach to a very good query.

GOESLINE:

I believe that the perishability concept came in with the difference between fresh fruits and vegetables and canned items that were considered nonperishable. It is comparable to handling head lettuce or cut-up chicken that has a 4-day storage life versus something that does not have to be watched too closely. I think that is how the "semi" part originated. It was to set these aside from products that have to be watched or they will go bad immediately, like a quart of milk versus milk in a can.

WOODROOF:

Just one point about the temperature. It seems to me, of all the temperatures we might use for all the products, there are a few critical temperatures that are important for us to determine. One of these is the temperature at which insects become active; that has been fairly well established—it being around 48° F. If you once get below that temperature the insect problem is solved. Another critical temperature is that at which fats melt—for example, candy bars, certain other

candies, cocoa powder, dried milk, and other items containing fats. Even though hydrogenated fats may be added, melting usually occurs around 95° F. It is important to know that other critical temperatures will markedly affect the products or packages—for example, the temperature at which a product freezes. This is especially important with fruits and vegetables.

J. R. WAGNER (Quartermaster Food and Container Institute) :

I would like to point out one temperature level that is quite critical. That is the point of freezing of canned goods.

WOODROOF :

I failed to mention that ; it should be considered.

WAGNER :

Some items are not seriously affected by freezing in storage while others are.

CHAIRMAN TRESSLER :

Upon examination of these items stored at minus 10° F., what products were seriously damaged by that low temperature ?

WOODROOF :

The only one is spun candies ; they crumble when frozen.

CHAIRMAN TRESSLER :

Wasn't there any canned fruit ?

WOODROOF :

We didn't include that in the first experiment, but are studying it now.

MITCHELL :

I would like to comment on the use of the 100° F. storage temperature. It does appear to approximate the temperature we get in a lot of warehouses during the summer months, not only in places like Arizona, but also places like Chicago where there have been many days at 100° F. Furthermore, a 100° F. temperature in laboratory studies serves, if for no other purpose, as an accelerated test. We can get the answer regarding the stability of a food item at least three to four times sooner if we use 100° than if we use 70° F. It is very useful in stability research investigations where we are comparing two or three products and would like to know the relative stability of each.

KUJAWSKI :

I gather that 6 months at 100° F. is not roughly equivalent to the 2 years at 70° F. If so, are you going to modify or change your concept of the relationship ?

MITCHELL :

In many cases they keep more than three times longer at 70° than at 100° F. At the present time we cannot state a relationship which would apply to all food items.

PORTER:

I was interested in Dr. Mitchell's comment on the accelerated test. I was looking back at Major Wodicka's article on the development of Army rations. In 1945, at the Conference on Fats and Oils, he reported (talking about using 125° F.) that it appeared that between 100° and 125° F. there were thresholds for many food products at which storage at higher temperatures actually changed the mechanisms so that deteriorative changes took place at higher temperatures which do not occur at lower temperatures. I wonder if anything like that occurred between 100° and 70° F.

MITCHELL:

Since we commonly encounter 100° F. temperatures in actual practice, I think we can legitimately accept that as the temperature at which we will get deterioration in food products of the type we are investigating.

MRAK:

In dried apricots, Mr. Porter, when the temperature is somewhat above 70°, but below 100° F., there is another mechanism that comes in. I think Dr. Mitchell is aware of it.

While I am up, I want to say to Colonel Kujawski that I also was horrified to see the word "semiperishable" in the Agenda, but I didn't think that I should put it that way. I think all foods are perishable. Perhaps the "semi" comes in, because we considered perishable items those that underwent microbial changes as indicated by Dr. Goresline. Now, we are concerned with chemical deterioration which is more widespread. We think of this in terms of semiperishable. I think the "semi" should be taken out of it.

There is another point I would like to bring out, Dr. Tressler. That is, I think we must bear in mind that the minute these foods are packed they start to deteriorate. This is something hard to drive home—that if foods are on their way and you send them across a desert in some of the temperatures that Mr. Porter encountered, those foods are really going to be stimulated to go downhill. Then if we put them in a warehouse where they get another shot in the arm, they are going down still more. Maybe when they leave this country they look all right, but, when they go across the ocean in a ship with temperatures of 80° or 90° F. they are further abused. When deterioration once starts, there is a continued downward trend. It never goes back. It always goes on from where it is. I think that should be kept in mind.

CHAIRMAN TRESSLER:

Undoubtedly, that is one reason why the dehydrated foods received in the South Pacific were in such poor condition.

III. EFFECT OF ATMOSPHERIC CHANGES ON PACKAGED RATIONS

Friday Session

4 December 1953

CHAIRMAN TRESSLER:

We are very fortunate to have Professor Carl Kayan with us today. Professor Kayan, head of the Mechanical Engineering Department, Columbia University, will speak to us on the "Control of Condensation on Cold Items."

Control of Condensation on Cold Items

CARL KAYAN

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Perhaps the best contribution I can make to the success of this conference is to talk in simple terms about the birth of a vapor-air mixture so that we may appreciate what really is involved. Suppose we have a simple tank as in figure 1. On it will be placed a pressure gauge to record the pressure and a thermometer to record the temperature.

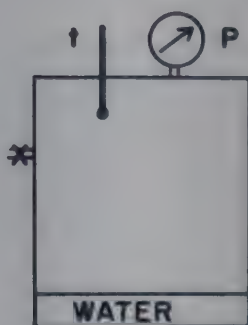


Figure 1

Next, it will be completely evacuated so as to be full of emptiness. Then some water will be introduced into the tank. Under those circumstances, that water surface will give off a vapor, there will be a vapor above the water, and it will be possible to measure that vapor pressure, which will vary with the temperature.

I might say, by way of example, at 100° F. the vapor pressure is about 1 pound per square inch absolute. That is about one-fifteenth of atmospheric pressure. We can also refer to that as 2 inches of mercury absolute. The various vapor pressures depend on the temperature.

Next a little valve at the side of the tank is opened and dry air allowed to go into the container. We will take one given moment at which this happens, and refer to figure 2. At the particular tempera-

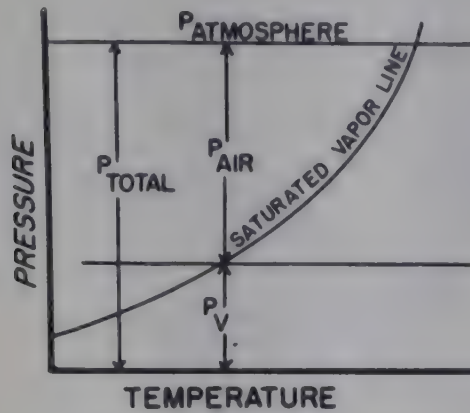


Figure 2

ture at which this has happened, vapor pressure (P_v) will be as indicated, and letting the air enter in turn will superimpose some additional contents on the tank which will be evident by what we call the air pressure—partial air pressure (P_{air}).

Now we have here two parts to this system—vapor pressure and air pressure. Thus we have a picture. So that you may know that the total mixture pressure is atmospheric pressure, we will mark it “atmosphere.” We now know that the total pressure of the atmosphere is accounted for by a partial air pressure and partial vapor pressure.

Next, let us just put an extension on this tank (fig. 3). In the tank

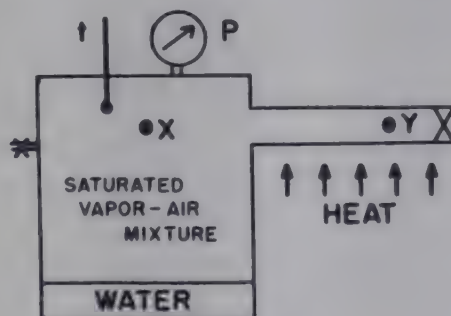


Figure 3

itself we have a mixture of vapor and air, and, under these circumstances of having a water surface, that mixture would be said to be saturated. That is a saturated mixture shown along the vapor line of figure 2—another term for that is 100 percent relative humidity. Now we have one line of the Psychrometric diagram.

Let us take the 100 percent relative humidity mixture at any given temperature condition, and move it out through the pipe extension of figure 3. Technically, this would be called “at constant pressure.” That is obvious, of course; and in moving it out through the pipe, let

us say we heat it. Its temperature goes up. I will show you what happens to the mixture (figure 4). The mixture will go from point

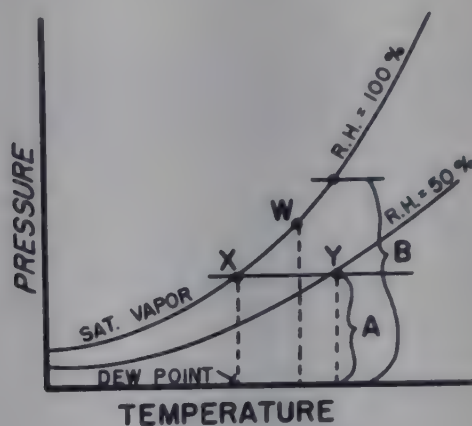


Figure 4

“X” to a higher temperature; thus, let us say it goes over to the right. We started at point “X” and over here we are at point “Y.” That is very, very interesting, because now you see we have a condition to the right of “X”—a hotter mixture—and we would note that the possible vapor pressure at that corresponding temperature is much more on the vapor line as compared with what it actually is. That enables us to say that the relative humidity at this point is less than 100 percent. As a matter of fact, we could define relative humidity as the partial vapor pressure actually existent, divided by the vapor pressure possible. That is very simple. It is value A compared to value B.

We could draw a complete psychrometric diagram. I can put a line through of constant relative humidity, and I devise this here to be 50 percent so we would have a line of 50 percent relative humidity. I shall show only this line for simplicity, although I could add 70, 40, 30, and so forth, making the psychrometric diagram. What that says is that at point “Y” the vapor-air mixture is not saturated. It has a relative humidity of less than 100 percent—said relative humidity depending on its birth conditions at point “X.” We can refer it back to here at point “Y,” and we could call the corresponding temperature the dry-bulb temperature. The temperature at “X” call the saturation temperature, for the moment. That is the temperature at which the vapor was born, registering a certain amount of pressure, and now, please bear in mind, the mixture is away from the liquid contact. That is important. A relative humidity is indicated. We might interpose—one additional temperature here, just by way of reference, is useful. This will be an equilibrium (point “W”) or wet-bulb temperature which we can include. We now can talk about three temperatures—the temperature of the mixture, which we call the dry-bulb temperature, a saturation temperature, and wet-bulb temperature, corresponding to points Y, X, and W, respectively.

Considering a mixture of point “Y”—if in turn we cooled that mixture, it would go in the left direction, and there would be a point where the vapor pressure in the system would just come onto the saturation line. This is the condensation point. That is the point of danger as far as storage conditions are concerned, particularly taking goods out of storage. So we might alternately refer to this as the Dew Point. When we cool a mixture, or subject it to cold-surface contact, it comes to a point to where it will just start to form dew.

Now we have another idea coming into the picture which is very pertinent to our whole argument (fig. 5). Here we have a mixture—

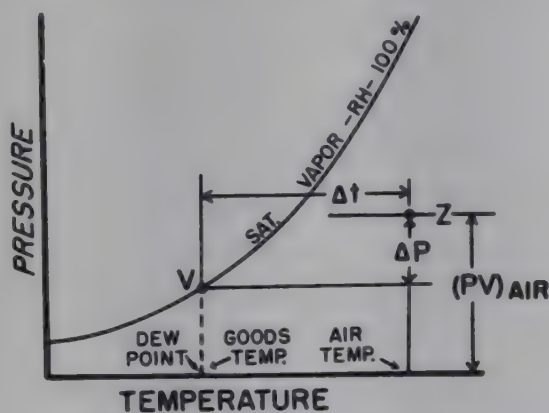


Figure 5.

I will label it point “Z”—at some given temperature, at some relative humidity. In this particular case it is on the 50 percent line. It could be higher, but the useful point I want you to note is this: if this mixture in turn were exposed to a surface whose temperature corresponded with a point “V” in which we would have a corresponding vapor pressure, then we might show it as a line lower than vapor pressure in the mixture. This is the line corresponding to the vapor pressure that would exist on the cold surface, and here in turn we have a vapor pressure difference ΔP which is the driving force pushing towards condensation. If in turn we wish to avoid condensation, we must avoid that pressure difference.

Now, just what does that mean? That means if we have had goods at a temperature as indicated at point “V,” those goods at that temperature with a possible vapor pressure condition at this level must never be subjected to an atmosphere at any temperature off to the right in which the vapor pressure is higher than that. If the vapor pressure in the atmosphere is higher than indicated by this dew point line, then we will have condensation. Specifically, it means that if you have stored goods at this particular temperature, say it is 45° F., the vapor pressure is three-tenths of an inch of mercury. If in turn I take 45° F. material out of storage and bring it out into a normal atmosphere (higher in temperature and to the right on the diagram), the relative humidity in that atmosphere anywhere along there must

always be such that the vapor pressure will be less than this amount. That means, for different temperatures of air there will be different relative humidities. To enable you to get numbers relatively easy, a variety of different charts have been constructed. The Refrigeration Research Foundation has a chart dealing with that, and so has the Quartermaster Institute. Before examining the chart, let us recall that we have been able to talk about dew point. We have been able to talk about relative humidity. We have defined what relative humidity means. We have talked about this vapor pressure difference. Everything we do is to control this vapor pressure difference so that we don't have it, because it is the vapor pressure difference that will force vapor onto the cold surface, even if that surface is inside of a package. If the cold surface is inside of a package, it means the vapor pressure must go through that package barrier, transcend its permeability, and the goodness of that barrier is based on its ability to resist that vapor pressure difference. We might also have a time-wise temperature variation, but let us remain with the vapor pressure situation. We want to keep that vapor pressure down below that point corresponding to the dew point.

On this particular chart, we will imagine we have various transfer room temperatures, temperatures of mixtures that are possible, and different relative humidities. There are all sorts of combinations we could run into. Let us presume we have a 40° F. surface, as indicated on the diagram. We have been storing for a period of time at 40° F. Thus the material is at 40° F., and we wish to bring that out of storage, and we don't want any condensation. Under those circumstances, on this particular chart, if we moved from the 40° F. condition into a room of 55° F.—the middle line in this particular case—the permissible relative humidity would be 60 percent. We could have as much as that. If we had more than that, we would get condensation. Why? Because under the circumstances, the permissible value is along this line, relative humidity as indicated by such a point. If in turn the relative humidity at a given room temperature is higher, it simply means we move up the line to a maximum of 100 percent, but anywhere we move above this point, in turn we get more vapor pressure and a bigger vapor pressure difference. It is the difference that is doing the damage. So we might note for a 40° F. item we could have in a 55° F. atmosphere something like 60 percent humidity.

For the 40° F. material, if we went into a 60° F. room, then in turn we would have less relative humidity involved—50 percent. If we moved a 40° F. condition into a 70° F. room, the maximum relative humidity permissible would be approximately 35 percent. That simply means that for a dew point or a surface condition of a designated temperature, there would be a permissible relative humidity of a given value. That means that the room to which we transfer must be air-

conditioned to the particular atmospheric condition desired, to the particular relative humidity, and that may be a mechanical problem to achieve.

We also note (fig. 5), beyond the consideration of the pressure difference there, that we have likewise a temperature difference ΔT between the atmosphere and the cold material. That means the atmosphere will tend to warm up the cold material. What that means in effect is that as the cold material warms up it will march along the curved vapor line and that progressively higher and higher relative humidities in the transfer room atmosphere are permissible. The heating-up operation which takes place is so-called "transient heating operation." It takes time to accomplish the result, and during that time element while it is trying to warm up in its various locations within the package, from the outside surface inward to the deepest core, simultaneously the vapor pressure difference that we might have between the outside atmosphere and the cold surface is driving moisture, or tending to drive moisture, towards the cold material. It is that tendency of moisture to drive under the vapor pressure difference that in turn must be resisted by different types of barriers.

So the control of condensation, as far as refrigerated products are concerned, is to be found in at least two principal elements: first, control of the transfer room relative humidity as we have illustrated and, secondly, types of packaging. Both of these subjects, I take it, are of particular and pertinent interest here at this conference.

CHAIRMAN TRESSLER:

We have another speaker on this same general topic. It so happens that The Refrigeration Research Foundation, in cooperation with the Quartermaster Food and Container Institute, has carried out some work in Professor Woodroof's laboratory at the Georgia Experiment Station. Mr. E. K. Heaton, one of Dr. Woodroof's assistants, is here to explain what he has done in that field.

Condensation Effects of Temperature-Humidity Changes

E. K. HEATON

Georgia Agricultural Experiment Station

Numerous tests have been conducted using 50 cases of Combat Rations in V-board cartons. The results can be quickly comprehended in table 1.

Cases were allowed to remain at the low temperature for 2 months so that the temperature and humidity would equalize. In some instances the cases of rations were used several times.

Observations on instances where no condensation occurred on outside nor on inside of cases. Cases of rations were moved from 47° F.

Table 1. *Effect of various temperatures and relative humidities on U-board cartons*

Range of Temperature and R. H.	Effect
47° F. at 90 percent r. h. to 100° F. at 90 percent r. h.	Slight condensation, exterior only.
47° F. at 90 percent r. h. to 100° F. at 50 percent r. h.	No condensation.
47° F. at 90 percent r. h. to 70° F. at 90 percent r. h.	Slight condensation, exterior only.
47° F. at 90 percent r. h. to 70° F. at 50 percent r. h.	No condensation.
32° F. at 90 percent r. h. to 100° F. at 90 percent r. h.	Slight condensation, exterior only.
32° F. at 90 percent r. h. to 100° F. at 50 percent r. h.	No condensation.
32° F. at 90 percent r. h. to 70° F. at 90 percent r. h.	Slight condensation, exterior only.
32° F. at 90 percent r. h. to 70° F. at 50 percent r. h.	No condensation.
32° F. at 50 percent r. h. to 100° F. at 90 percent r. h.	Slight condensation, exterior only.
32° F. at 50 percent r. h. to 100° F. at 50 percent r. h.	No condensation.
32° F. at 50 percent r. h. to 70° F. at 90 percent r. h.	Slight condensation, exterior only.
32° F. at 50 percent r. h. to 70° F. at 50 percent r. h.	No condensation.
-10° F. at equilibrium r. h. to 100° F. at 90 percent r. h.	Heavy condensation, exterior; moderate condensation on cans.
-10° F. at equilibrium r. h. to 100° F. at 50 percent r. h.	Slight condensation, exterior; moderate condensation on cans.
-10° F. at equilibrium r. h. to 70° F. at 90 percent r. h.	Slight condensation, exterior; slight condensation on cans.
-10° F. at equilibrium r. h. to 70° F. at 50 percent r. h.	Slight condensation, exterior; slight condensation on cans.

and 32° to 70° or 100° F. at 50 percent r. h. without visible condensation on the outside of the cases. Careful examination of the cans showed that they were also free from condensation.

Observations on instances where condensation occurred on outside of cases only. When cases were moved from 47° F. and 32° to 70° or 100° F. at 90 percent r. h., condensation immediately formed on the outside of the cases; however, it soon disappeared. In a few instances, sweating was sufficient to form droplets that ran down the sides. Careful examination of the individual rations immediately after reaching room temperature showed that, although some condensation of moisture occurred on the outside of the cases, none of it penetrated

the package beyond the waterproof asphalt layer. The condensation was either absorbed by, ran off, or evaporated from the cases without affecting the contents.

Observation on instances where condensation occurred on outside and inside of cases. When shifted from minus 10° F. at equilibrium relative humidity to 100° or 70° F. at 90 percent r. h., condensation was heavy enough in some instances to run off the outside of the cases. There was a moderate amount of condensation on the can surfaces of heavy items, such as canned meats, but none on the items such as B-units and accessory packets; however, it soon evaporated and was absorbed by the cardboard.

When shifted from minus 10° F. at equilibrium r. h. to 100° or 70° F. at 50 percent r. h., enough moisture condensed on the outside of the cases to cause them to feel damp. Condensation was moderate on the canned meat items, but it soon dried off.

All the rations from minus 10° F. remained at room conditions (75° F., 50 percent r. h.) for an additional month and were then re-examined. No damage due to moisture condensation was found.

Summary

The studies certainly demonstrate that whenever changes in temperature occur, relative humidity must be reckoned with. However, when V-board containers are used, the relative humidity does not appear to be too critical a factor. The tests further showed that C Rations in V-board containers can be satisfactorily stored at 32° F. and about 70 percent relative humidity; also, that these same rations could be safely removed from this storage to field conditions without step-by-step tempering.

CHAIRMAN TRESSLER:

I believe this work demonstrates that it is perfectly practical to store the assembled rations in V-board cases at temperatures as low as 32° F. and bring them out at higher humidities. Even though you have condensation on the outside of the case, the condensation on the cans themselves will not be sufficient to cause great trouble. This it seems to me is a very important point.

IV. ECONOMICS OF COLD STORAGE OF FIELD RATIONS COMPARED WITH DRY STORAGE OF RATIONS

CHAIRMAN TRESSLER:

Now we come to the point of decisions and proposed actions. First we will take up the question of whether it is economically practical to cool-store rations and, secondly, whether or not the present system of assembling the field rations in the V-board cartons, as they are now doing it, is the better way, or whether it might be more advantageous to store the individual components—to stockpile the individual components, we will say—in cool storage, and then assemble them as required.

Major W. C. Fischer of the Military Operations Office of the Food and Container Institute has made a rather comprehensive staff study which he has summarized particularly for you.

Disadvantages of Forced Feeding of Operational Rations

MAJOR W. C. FISCHER

Military Liaison Office, Quartermaster Food and Container Institute for the Armed Forces

What is forced feeding?

In general, it can be assumed to be the arbitrary disposition of any type of ration or ration component issued to achieve turnover. Upon inquiry, however, it would appear that the term "forced feeding" has a bad connotation. Agencies which would be expected to be concerned with this procedure are reluctant to admit knowledge of the term. Personnel consulted on the point stated that "forced feeding" had another name at their installation—just what could not be ascertained. The term "substitution" seemed to be most commonly used.

It is obvious that forced feeding is being used and that it has a legitimate purpose. We know, for example, that when components of the B Ration show signs of age or other deterioration, they are moved into the feeding program and used. Care is taken, of course, to insure that the products are in safe and edible condition. A good example of the effective use of forced feeding can be found in actual instances of savings effected at depot level—one at Fort Worth, another at Columbus, and a third at Atlanta—where, due to action recommended

in surveillance reports, certain food items were pushed into issue. Actual figures from a few of these reports, for the period 1 September 1953 to 3 November 1953, may be illuminating. At Fort Worth, 225,212 units of canned fruits and vegetables were saved during this period. At Columbus, 172,383 units of canned fruits and vegetables were saved. At Atlanta, 15,516 units were saved. Time did not permit me to compile a complete and accurate report on savings effected by all Quartermaster depots for a given period, but no one would question, I think, the need for such action. The economic advantage, at least on the surface, looks good. We shall look into this aspect somewhat more critically in a moment.

When we come to the issue of the special-purpose ration we also have advantages: (a) such issue familiarizes the troops with operational rations; (b) it maintains a system of turnover for these stocks of rations, a necessary system since without it the rations would be rendered useless by old age.

What are the disadvantages of forced feeding?

To explain them it is necessary to go behind the scenes for a moment. When the Ration, Individual, Combat, C, and the Ration, Small Detachment, 5-in-1, are fed under a forced feeding pattern, the ratio for issue is 65 to 35—that is, 65 percent of the day's issue are C Rations, and 35 percent are 5-in-1.

The method of utilization varies with the mess personnel and food advisory personnel. At some stations, the components are issued during technical exercises, and the soldier eats the ration in the manner for which the ration was designed. This particular use is not considered forced feeding, since it was originally intended for such activities to supply ration stock rotation requirements. At other stations, ration components are integrated with the A Ration over a period of several days, which makes the presence of the operational ration component in the menu less noticeable. Still other stations heat and serve such components from the steam table inserts in the dining room.

The average age of such forced-fed rations is 2 years. Thus, the rations being served today were assembled in 1951. Some 1950 rations are still being consumed.

It should be emphasized that operational ration cartons do not necessarily contain 100 percent food. For example, the accessory packet of the C Ration is also issued along with the food components and it contains cigarettes, plastic spoon, can opener, toilet tissue, gum, and water-purification tablets.

It is evident from experience that two disadvantages arise from forced feeding of special-purpose rations: (a) lack of troop acceptance, and (b) lack of economy.

Let us first consider the effect on morale. While no firm data are available regarding waste at operational ration meals as compared to that of the A Ration, observers of the Food Service Division, Office of The Quartermaster General, have stated that the present method of utilization in messes appears to be demoralizing to using agencies and creates absenteeism from the mess on those days the ration is served. Furthermore, those who do eat the operational ration leave an excessive amount of waste, resulting in further ineffective utilization. This waste and absenteeism underscores the bad morale effect. However, it must be borne in mind that the "dislike" in the continental United States stems in great measure from the psychological factor that the A Ration is available, but is being supplanted by an undesirable ration. An adequate comparison between the 2 types of rations cannot be made from the acceptance standpoint because of the specific purpose of the one for technical use in adverse logistical situations.

No data are available regarding the patronizing of PX, restaurant, and snack bars on the days operational rations are served, but it is obvious that personnel who absent themselves in droves from the messes on those days do eat somewhere.

Now what about cost factors? The information available would appear to bear out the fact that certain field rations are not favorably received under the circumstances. During the period 1 October 1952 to 30 September 1953, 11,760,000 C Rations and 3,131,000 5-in-1 Rations were issued in the Zone of the Interior. (A total of 14,891,000 units.) The C Ration is charged out at a cost of \$2.17, and the 5-in-1 at a cost of \$1.94. This may be contrasted with the price of the A Ration, which, at the Schenectady Depot, cost \$0.9779 in October 1953.

If we can use 100 men as one unit and feed this unit on the percentage given above (65 percent "C" and 35 percent "5-in-1"), the cost of 35 5-in-1's at \$1.94 is \$67.90, and the cost of 65 C's is \$141.05; total cost, \$208.75. Similar cost for this unit on A Ration is \$97.79, or a difference of \$111.16. Since 14,891,000 combined C and 5-in-1 Rations would represent 148,910 hundred-man units, the cost to the Army of feeding these operational rations *over* the cost for A Rations amounts to \$16,552,835.60. The figures just given should be considered only an indication of the large amount of money involved. Actually, the percentages were 79 percent and 21 percent. Therefore, an accurate calculation must be based, not on 65 percent C Rations, but 79 percent, which at the greater cost of the C Ration will increase the 16 million dollars plus to \$17,030,431. I believe Mr. Appel will use 79 percent and 21 percent in his talk.

Economically, that is a large figure, and it does not make allowance for double handling and longer storage periods involved for the C

and the 5-in-1. Yet, it must be remembered that economies or no, these rations must be stocked for ready use in time of emergency.

It is clear that the problem of forced feeding is closely linked with results of ration storage studies. If we can find out which of the components of a given special-purpose ration are going bad first, and under what conditions, we can perhaps find a way of obtaining longer stability for these items or can at least predict how long they can remain in storage before use is made of them. It may be that with full and reliable data on the storage life of packaged rations we can work out a formula that will modify, if not correct, some of the disadvantages of "forced feeding."

Storage of Operational Rations by Components, Compared to the Present Method of Packaged Rations

The Military Operations Office, Quartermaster Food and Container Institute, is gathering data for use in the preparation of a staff study on the subject I have just given. An outline indicating the scope of the study and the results we expect to receive should be of interest.

First—in our effort to determine whether storage by component would be feasible, better, and save money—we assume that large stocks of operational rations (approximating existing stocks) will continue to be purchased and stored for use in an emergency paralleling that of Korca.

The data we have collected tentatively indicate the following:

1. Advantages of the present system.
 - a. Allows the simplest type of stock control.
 - b. Provides large stocks for quick shipment.
 - c. A stand-by system of assemblers is not required.
2. Disadvantages of present system.—Tentatively, the study will attempt to determine the effect of occasional feeding of operational rations as it affects the troops, and especially what effect a negative attitude of troops might have on a ration at a time of real need for that ration (i. e., would a negative attitude force, say, the C Ration into discard, as happened to the K Ration?).
3. The study will try to find out how much money could be saved by *not* feeding operational rations; or by feeding only part of the operational ration. For example, we know that the cost of feeding the C Ration over that of the A Ration for a period of 1 year in the Zone of the Interior is approximately \$14,000,000. The study should indicate some excellent reasons why the issue of such items as accessory packets can be questioned.

The study is also pointing out the fact that monetary loss is sustained when rations are issued on the basis of their shortest lived components,

while other components may have 2 to 3 more years of storage life remaining.

We will attempt to show the disadvantage of packing items together when storage life and characteristics are different, and we hope to prove that storage by component will relieve problems of detection of spoiled packaged components and possible cost of repack. (For example, we knew that merely to remove spoiled components from a V-board overseas container would consume 18,000 man-hours at a cost of \$26,000 for 850,000 C Rations.)

The study may indicate that a good many problems always encountered with ration assemblers can be lessened or eliminated. Some of these are: Delay to an assembler because of late arrival of some components; consequent delay in receipt of the packaged product by the Government; consequent cause of substituting one item for another to permit assembly.

We are of the opinion that the study will show the following advantages for the proposed method:

- a. Components could more easily be checked for remaining storage life.
- b. Items could be issued and integrated with the A Ration to allow maximum acceptance.
- c. Large component requirements could be phased in with proper seasonal production.
- d. Repack would be eliminated.
- e. Components purchased could be the latest item evolved by the Institute and reflected in specification changes.
- f. Rations packed would contain the very latest developments, and items of a known quality (i. e., components of earlier manufacture could be packed first and shipped first).
- g. Rations in a quantity as determined by the Office of The Quartermaster General must be stored in a packed, ready-to-go condition. Governmental assembly lines can be maintained in a reasonable state of efficiency by packing these required rations.
- h. The system of storage by components should not affect any decision on cold storage of operational rations. Perhaps certain items would not require cold storage in any case, which might save a little of the extra cost of cold storage.

What is the proposed system of storage by components? Some of the foregoing remarks fairly well outlined it. Stated simply, it would be the procurement and storage of ration components without the assembly feature. Also, items such as cigarettes and candy, which might not respond satisfactorily to cold storage, would be purchased as needed. Components would be stored as "balanced" rations including

packaging materials. An alternative might be to assemble B-units and/or accessory packets only.

The percentage of rations already mentioned should be stored on a ready-to-go basis.

Ration assembly lines such as the one at the Chicago Quartermaster Depot should pack this ration reserve. Stand-by contracts with industry should be drawn so that components could be shipped to them in case of emergency.

A surveillance program should be used to check components for remaining storage life by periodic withdrawal and evaluation of samples.

Items would be issued near the end of their storage life and replaced by newer components.

The foregoing is a summary of what we will attempt to show in the completed study.

The following questions were encountered in the course of the study to date:

1. Would the cost of the surveillance program offset savings?
2. Would stock record accounting become too involved?
3. Would certain items require special handling and packaging, increasing the present cost (i. e., overpacking of B-unit items)?
4. Would coffee become caked?
5. Would cereals and candy become infested?
6. Would crackers stale?
7. Would water-purification tablets lose strength?
8. What happens if specifications are changed—what would be done with the food and packaging materials?
9. What happens if specifications are *not* changed—wouldn't this mean poor progress in ration development?
10. Would storage by components mean double handling and more expense?
11. Wouldn't this method require replacement of some items several times in relation to long-lived components?

Perhaps, in the discussion that is to follow, ideas and suggestions may be made that will stimulate a more thorough study of this problem.

CHAIRMAN TRESSLER:

A great deal of thought is going into this staff study, and we will await its appearance with great interest.

Dr. Woodroof has collected some data concerning the relative cost of cold storage and common storage, that is, storage at ordinary temperatures and storage at reduced temperatures under refrigeration. Would you present your figures, Dr. Woodroof?

Cost of Cold Storage and Dry Storage of Field Rations

J. G. WOODROOF

Department of Food Technology, Georgia Agricultural Experiment Station

What I have is largely in the way of a liaison between the Quartermaster Corps and the warehousemen, and I have collected certain information so as to know about what the cost would be and the availability.

Due to lack of standard account classifications, variations in different areas, and to regulations in reference to collusion, it is difficult to discuss costs of storage. Costs are divided into *storage* and *handling*, and are based on package density or package displacement, with varying floor loads and pile heights. Some warehouses add in-and-out handling to the first month's storage, others prorate it over several months, but in either case it is fixed, irrespective of the time of storage. Other factors in price determination are: valuation susceptibility to claims, size of lots received, labor availability and cost, the condition of storage, turnover, excessive loss of space in piling, propinquity of commodities, competition, desired temperature, location in country, etc.

Data in table 1 show the cold storage tariff, per cwt. (hundred-weight), per month, of 11 representative items held in cooler (32° to 36° F.) and freezer (0° to -15° F.) storage in several sections of

Table 1. Cold storage warehouse tariff on 11 non-military items, CWT, per month on 15,000 pounds and over

Commodity	Location	Handling*	Storage
Cooler (32° to 36° F.)			
Butter	Chicago	Cents	Cents
		19	15
Cheese		18	13
	St. Louis	19	15
	Atlanta	25	15
	Boston	20	13
	Chicago	21	13
		17. 5	12. 5
Confections	Kansas City	18	12
	St. Louis	17. 5	12. 5
	Atlanta	37	25
	Boston	25	17
	Chicago	24	16
Dried Eggs	Atlanta	35	20
	Chicago	20	19
		19. 5	19

*Fixed, irrespective of length of storage.

Table 1. Cold storage warehouse tariff on 11 non-military items, CWT, per month on 15,000 pounds and over—Continued

Commodity	Location	Handling*	Storage
Cooler (32° to 36° F.)			
		<i>Cents</i>	<i>Cents</i>
Dried Eggs—Continued	Kansas City-----	21	17
	St. Louis-----	19. 5	19
Dried Fish-----	Boston-----	25	18
Dried Fruit-----	Atlanta-----	25	15
	Boston-----	22	12
	Chicago-----	16	12
		16	14
	St. Louis-----	16	14
Shelled Nuts-----	Atlanta-----	30	20
	Boston-----	22	13
	Chicago-----	16	16
		17. 5	17
	Kansas City-----	13	10
	St. Louis-----	12. 5	10
Freezer (0° to -15° F.)			
Butter-----	Chicago-----	25	17
		27	16
	Kansas City-----	25	15
	St. Louis-----	25	17
Confections-----	Chicago-----	40	30
Dried Eggs-----	St. Louis-----	22. 5	25
	Chicago-----	22. 5	25
Shelled Nuts-----	St. Louis-----	19	17
	Chicago-----	25	22. 5

*Fixed, irrespective of length of storage.

the country. The tariff on *handling* in the cooler varies as much as 30 percent, in different sections of the country, while that of *storage* is more nearly the same. Additional charges are made for quick freezing, sorting, transferring, marking packages, or performing other services requiring extra labor or materials.

Warehousemen develop their own precepts of usable space, occupancy, desired revenue, analyze their own commodity receipts, and plot their own curves peculiar to their individual situations.

In table 2 is shown cold storage warehouse tariff on B-2 units of C Rations, and Dry Packs of 5-in-1 Rations, in cooler (32° to 36° F.) and freezer (0° to -15° F.) storage for two warehousemen in Chicago. This shows a handling charge in-an-out of cooler storage of 7.8¢ and 5.8¢ for 39-pound C Rations and 29-pound 5-in-1 Rations, respectively.

Table 2. Cold storage warehouse tariff on two military rations, in cooler and freezer storage, per ration, on 15,000 pounds and over

Storage Tariff at 32° to 36° F.

Rations	Handling* (\$)	Storage	
		Yearly (\$)	Monthly (\$)
C 39 lbs.-----	0. 078	0. 608	0. 051
5-in-1 29 lbs.-----	. 058	. 452	. 38

Storage Tariff at Cooler and Freezer Storage

Rations	Cooler (32° to 36° F.)			Freezer (0° to -15° F.)		
	Handling* (\$)	Storage		Handling* (\$)	Storage	
		Yearly (\$)	Monthly (\$)		Yearly (\$)	Monthly (\$)
C 39 lbs.-----	0. 078	0. 744	0. 062	0. 078	1. 18	0. 098
5-in-1 29 lbs.-----	. 058	. 552	. 046	. 055	. 876	. 073

*Fixed, irrespective of length of storage.

The storage tariff is about 6¢ and 4¢ per month, respectively. These figures as given are the same, irrespective of the period of storage.

CHAIRMAN TRESSLER:

Assuming it was in there for 3 years.

WOODROOF:

So far as I have been able to figure, it is the same.

CHAIRMAN TRESSLER:

I mean, figuring out what would be the cost per ration.

WOODROOF:

It is 60¢ a year for storage of a single 39-pound C Ration, and it is 45¢ a year for storing a 29-pound 5-in-1 Ration.

LT. COLONEL JOHN W. MAXWELL (Office of The Quartermaster General):

You refer to a C Ration weighing 39 pounds?

WOODROOF:

Yes.

MAXWELL:

That would be divisible by six.

WOODROOF:

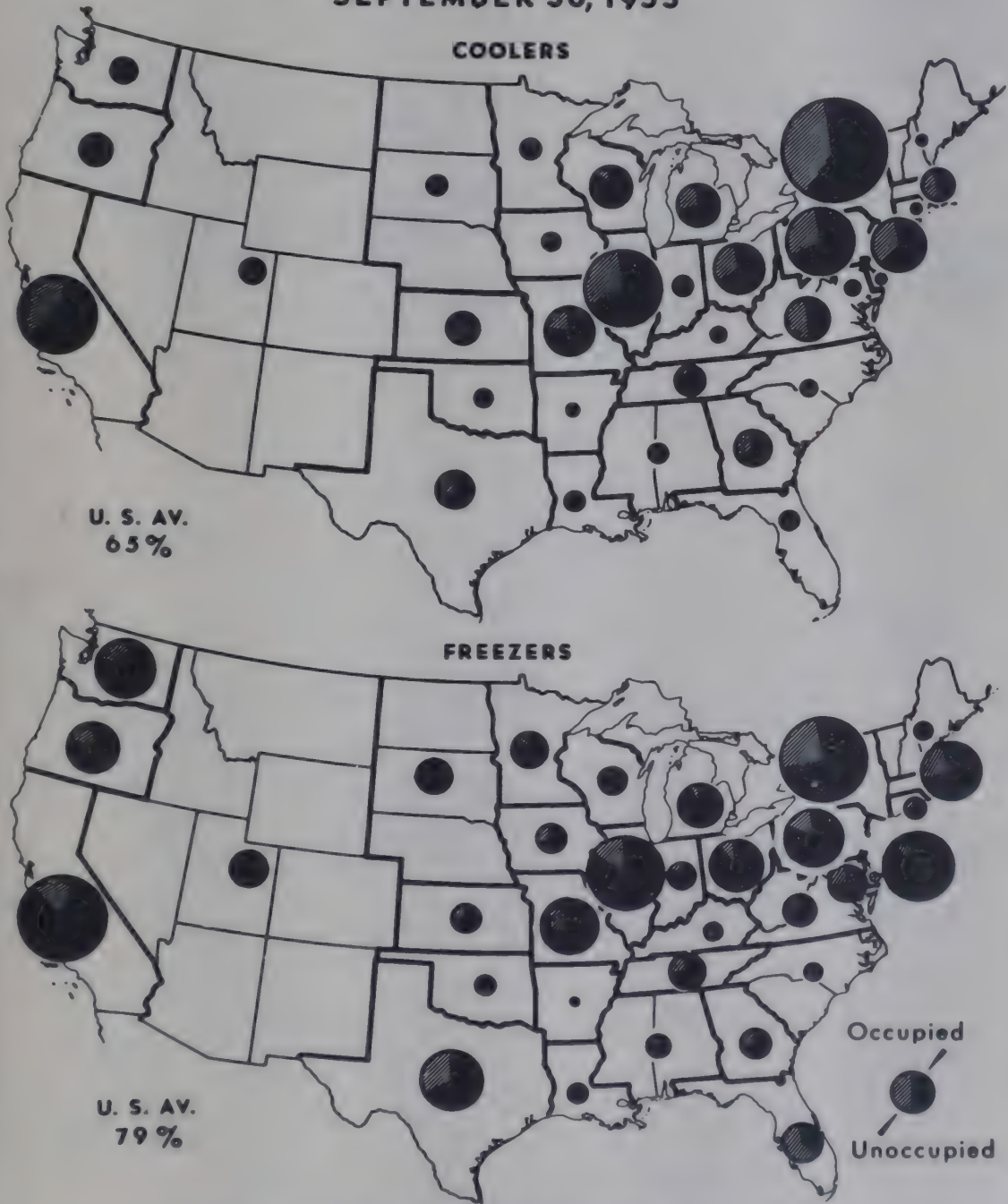
You are right. That makes it appear a good deal better than I showed. Now we also have figures storing them at lower temperatures.

Handling in-and-out of freezer storage is about the same as for cooler storage, while the storage tariff is higher—being about 10¢ for 39-pound C Rations and 7¢ for 29-pound 5-in-1 Rations.

CHAIRMAN TRESSLER:

How does that compare with costs for common storage?

PUBLIC GENERAL COLD-STORAGE WAREHOUSES
(APPLE HOUSES EXCLUDED)
PERCENTAGE OF SPACE OCCUPIED
SEPTEMBER 30, 1953



Areas of circles are in proportion to net piling space reported for the October 1, 1951 biennial space survey. See table 4

Figure 1.

WOODROOF:

That is another angle, but there is no storage except on the west coast. These figures were obtained from Production and Marketing in Washington. (See figs. 1 and 2.)

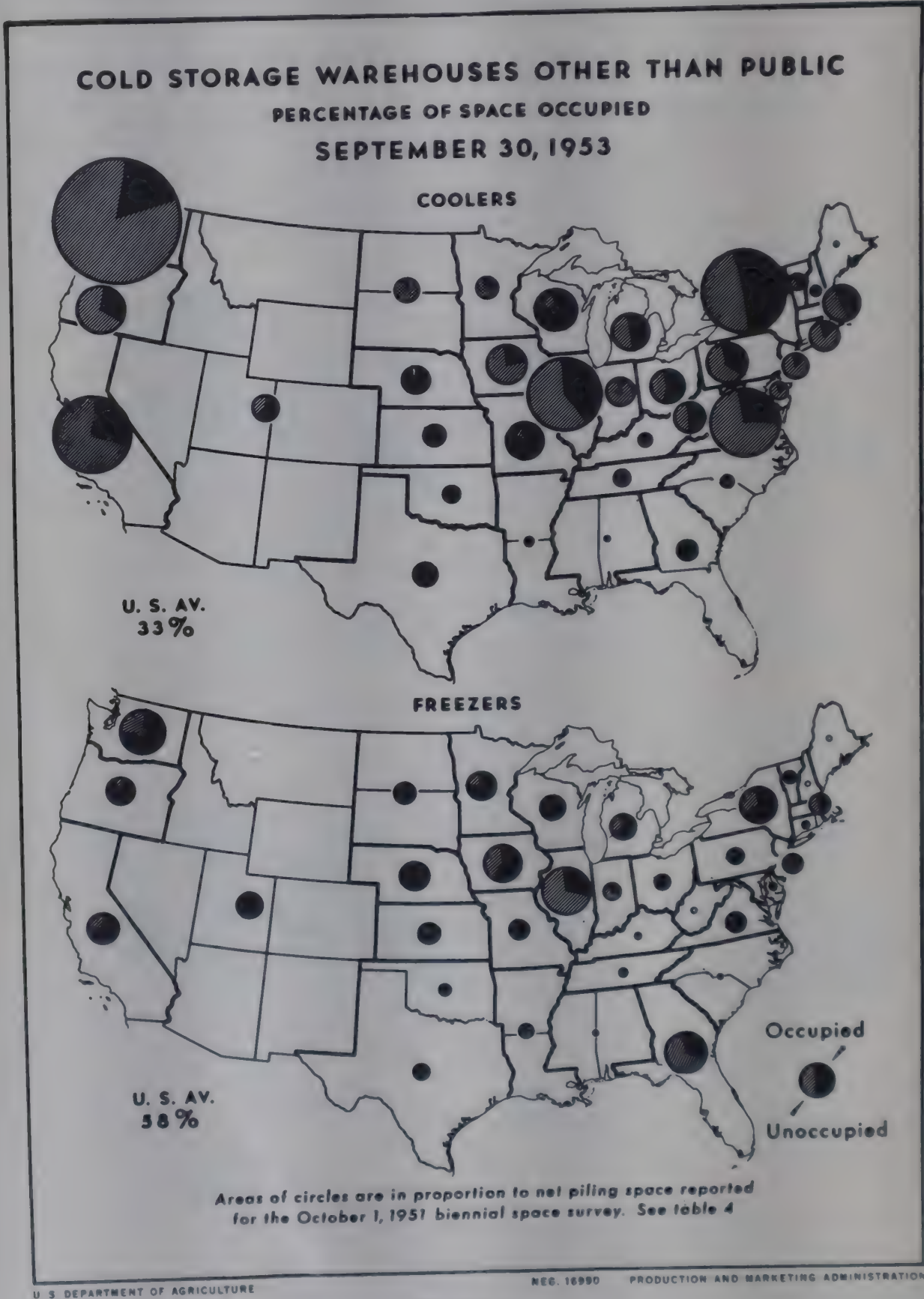


Figure 2.

CHAIRMAN TRESSLER:

I think the question we want answered is whether or not it is cheaper to put these rations in common storage for a period of 2 years and then force-issue them and buy additional rations. Remember, when they are force-issued under present conditions they replace the A Ration which costs less than half as much. Is it cheaper to do that or put all the rations in cool storage and hold them for 4 or 5 years and pay slightly more for storage rate and then use them. It eliminates at least one forced issue because certainly they will keep in good condition in the cooler at least twice as long. I think the evidence presented yesterday indicated at least three times as long. So we could at least save one forced issue, as I see it.

We have here today a man who knows a great deal about cold storage rates and so forth. When I looked around for someone to discuss the talks that you have heard by Major Fischer and Dr. Woodroof, I thought of Vallee Appel. He will report on the information which he has collected and discuss the talks presented by Major Fischer and Dr. Woodroof.

Advantages of Cold Storage of Emergency Type Rations

VALLEE O. APPEL

Office of The Quartermaster General

In order that there may be no confusion I wish to record that my remarks at this meeting shall be confined strictly to the storage of the Army emergency field ration. This ration is variously named and described, but I believe that we are all conversant with its nature and contents. Although there are various sizes and types of the emergency ration, I shall use the term "C Ration" in this discussion as descriptive of the entire class of emergency rations.

My appearance on this program is as a consultant on refrigeration to the Office of The Quartermaster General. In this capacity I follow a very pleasant avocation. I make my living as an operator of a commercial cold storage warehouse. In the course of my remarks to you I shall presume to express certain opinions and conclusions. In these I am biased, but only by the facts which support those opinions and conclusions. Because our warehouse is not now seeking and probably will not seek storage of the C Ration, I think that I can reasonably relieve myself of a suspected bias from a monetary standpoint.

In discussions relating to the correct storage of the C Ration previous to this meeting, and in this meeting yesterday and today, there appear honest differences of opinion, all of which must be and can be rationalized by proper research and by the passing of time—indeed perhaps earlier. There is one very definite opinion which we all hold

in common—that is, that the emergency ration is very much a military necessity and as such must be ever ready and carefully preserved for its sole indicated purpose—use in an emergency.

My assignment here is to discuss economics of cold storage of field rations compared with dry storage of these rations. Economics as used here certainly means cost, and cost cannot become a factor until it is determined that cold storage is or is not definitely preferable to other storage procedures. If and when it can be established beyond a reasonable doubt that controlled temperature and humidity storage of the C Ration is the correct form of storage, the question of cost or economics is purely an academic one.

It is my understanding that the C Ration is presently kept solely in unrefrigerated or so-called dry storages, in various geographical and climatic locations, with no particular attempt to obtain uniformity in storage conditions or to assure control of temperatures and humidities. Since valuable perishable food is involved, I am certain that the ordinary and least informed man on the street would opine that something better in warehousing could and should be devised if it is expected that this food is to be properly preserved for future use in an emergency.

In the distinguished group here assembled I would not dare to pose as a food technologist or a reasonable facsimile of one. However, from over 30 years of rather intimate association with perishable foods and observation of their affinities to temperatures and humidities, I have of course acquired some bits of valuable practical knowledge. This background, I believe, permits me to speak out in this discussion without hesitation.

I know the food items that are packaged in the C Ration. I am aware of their keeping qualities in storage. I am certain beyond a doubt that present methods of storage are erroneous and wasteful. I am equally certain that the C Ration and its constituent food items can be stored and preserved much better and longer in controlled cold temperatures and controlled humidities.

We are all aware that Government-sponsored projects are in process to determine through technical experimentation and study the ideal storage conditions for the C Ration. These projects are most worthy and must have our wholehearted support, but in this instance time is of the essence. Vast quantities of the ration are deteriorating and wasting under present storage arrangements. Every authority who addressed this meeting yesterday and today agrees that controlled refrigeration appears to be the answer. Under the circumstances is it prudent to wait 3 or more years longer for absolute technical proof? I think not. And, were I charged with the responsibility for the care of these emergency rations, I would be somewhat concerned over a delay in effecting a change.

Storage of the C Ration came to the attention of refrigerated warehouse operators a year-and-a-half ago. We were requested by the Army to submit rates for the handling and storage of the emergency ration. Specified were temperatures in a range of 45° to 55° F. and a relative humidity of 30 percent or less. It was generally agreed in our industry that both temperature and humidity requirements were impractical. The exceedingly low humidity is difficult if not impossible to obtain and maintain. The requested temperatures are not widely available in the industry. Few products are normally stored at these high refrigerated temperatures; hence a room only partially occupied with the emergency ration cannot be utilized for other purposes, and its earning capacity is thereby limited. As a result, most warehousemen would be inclined from a profit standpoint to charge a higher rate for a 45° to 50° F. temperature than for the much more generally acceptable temperature of 30° to 33° F.

The commercial warehousing industry was not advised as to the Army's potential storage volume of C Ration. It was assumed that the tonnage would be sizable requiring a considerable cubic footage of refrigerated space. I believe I can state without fear of contradiction that a considerable cubic footage would not be available to the Army in commercial warehouses at a prescribed temperature of 45° to 55° F., but ample space would be available at 30° to 33° F. or at sub-zero temperatures. Furthermore, irrespective of space availability, we of the cold storage industry are certain that the C Ration can best be preserved and for a longer period of time at 30° to 33° F. or subzero temperatures.

As far as I am aware, there are no published tariffs in the refrigerated warehousing industry which contain rate quotations on the handling and storage of Army emergency rations. Likewise, I am unaware of these rations being stored in any appreciable volume in refrigerated warehouses. At a result of this lack of experience, it is necessary to assume certain facts and factors relating to the ration in order to project probable storage and handling rates. Assumptions herewith made, however, are closely in line with precedents governing similar food items in rate determination and are influenced by actual offers made by warehouses to the Government. I am informed that last year five or more refrigerated warehouses submitted storage and handling rates to the Army for approximately 1,000 cars of C Ration. These rates varied from a high for handling of 18¢ per cwt. and a high for storage of 17½¢ per cwt. per month. The average of all the rates submitted was 13¢ per cwt. handling and 15¢ per cwt. per month storage. Density per cubic foot of space occupied usually dictates the storage rate of a commodity. Time consumed multiplied by the labor cost per hour usually determines the handling cost of a commodity. Density of the C Ration based on size and weights fur-

nished by the Army would lead me to believe that in fabricating a rate the aforementioned average of 13¢ per cwt. handling and 15¢ per cwt. storage might well be considered fair and acceptable rates for cold storage. It is my opinion that we can reasonably use these rates in estimating the cost of storing the C Ration in public refrigerated warehouses.

Next let us consider the probable rates in public dry or merchandise warehouses and the cost to the Government in storing the C Ration either in public dry warehouses or in Army-owned-and-operated dry warehouses.

Based on numerous observations, I would venture to say that the original cost of facilities and cost of operation are greater under Government auspices than under private or civilian investment and management. The only appreciable advantage to a Government operation is in tax-saving which, of course, is offset as far as the Government is concerned if a private enterprise pays no tax because it has no business.

Four of the largest merchandise warehouses in Chicago were recently contacted by my office and inquiry made as to their rates on packages similar in size and weight to the C Ration. The average rates given were 20¢ per cwt. for handling and 7¢ per cwt. per month for storage. I believe these rates may be considered representative of rates generally prevailing in the industry and, in computing costs, might properly be made applicable to Government-owned and operated installations.

On the premise that my calculations of rates for cold and dry storage are reasonably correct, I arrive at the following costs for the storage of the C Ration. In cooler storage at a recommended temperature of 30° to 33° F. and relative humidity of 60° F. at rates of 13¢ handling and 15¢ storage, 100 pounds of C Ration can be carried for 1 year at a cost of \$1.93; 1,000,000 pounds at a cost of \$19,300. One hundred pounds can be carried for 5 years at a cost of \$9.13 and 1,000,000 pounds at \$91,300. In dry storage, 100 pounds of C Ration can be carried for 1 year at a cost of \$1.04, and 1,000,000 pounds at a cost of \$10,400.

I do not know the average life of the C Ration presently stored in unrefrigerated warehouses, but from various discussions at this meeting I would assume that the ration must be a forced-issue item after 2 years, and if held longer than 2 years the ration is practically a total loss.

What are the economics involved?

In his excellent paper presented here today, Major Fischer stated: "During the period 1 October 1952 to 30 September 1953, 11,760,000 C Rations and 3,131,000 5-in-1 Rations were issued in the Zone of the Interior, a total of 14,891,000 units. The C Ration is charged

out at a cost of \$2.17 and the 5-in-1 at a cost of \$1.94. This may be contrasted with the price of the A Ration, which, at the Schenectady Depot, cost \$0.9779 in October 1953." In this statement, Major Fischer, of course, refers to a forced issue of the emergency rations. Based on these figures, I conclude that approximately 92,600,000 pounds were subjected to forced issue after 2 years in storage, and that in all probability some 200,000,000 pounds of various types of emergency rations are being stockpiled by the Army. This volume would represent about 33,000,000 C Rations which at \$2.17 per ration would indicate an investment of \$70,000,000 or thereabouts. These figures certainly make quite evident the fact that we are not discussing small change.

A further projection of Major Fischer's data would indicate that the 14,891,000 units force-issued in 12 months cost \$31,593,000, the cost of the A Ration (Schenectady) 14,891,000 units would be \$14,561,000—a loss sustained of \$17,000,000 because of the forced issue. Cost of storage for 2 years would add another \$1,000,000 to this staggering loss. Since there is a continuing production of the C Ration we must necessarily conclude that there ensues an \$18,000,000 loss through forced issue each year under the prevailing system of storage.

After the first year, with the elimination of the handling charge, 92,600,000 pounds of C Rations can be carried in cold storage each year for \$1,666,800; 92,600,000 pounds of C Rations can be carried for over 10 years in cold storage for the amount of a 1-year loss of \$18,000,000 suffered by the Government under present storage procedures. Patently, these figures strongly command our interest and should spur our ingenuity in search of means for correction.

As I affirmed in the beginning, I reaffirm now my conviction that storage of the ration in controlled cold temperatures and regulated humidity is the logical answer to our problem. I feel certain that the ration can be well kept for 5 years under proper atmospheric conditions. If the life of the ration is prolonged for only a year, "economics of cold storage" would demand a change in warehousing methods—and definitely, the sooner the better.

CHAIRMAN TRESSLER:

It seems to me that Mr. Vallee Appel has given you a very concrete, definite contribution. He has shown very clearly even for a period of 2 years you cannot afford to do anything else but store the field rations under refrigeration.

One thing that I haven't thus far given due credit for is that Mr. Haugh of our Engineering Services has worked out a useful chart relating to the transfer of stored items from one level of temperature to another. (See fig. 1.)

Moisture Condensation Chart

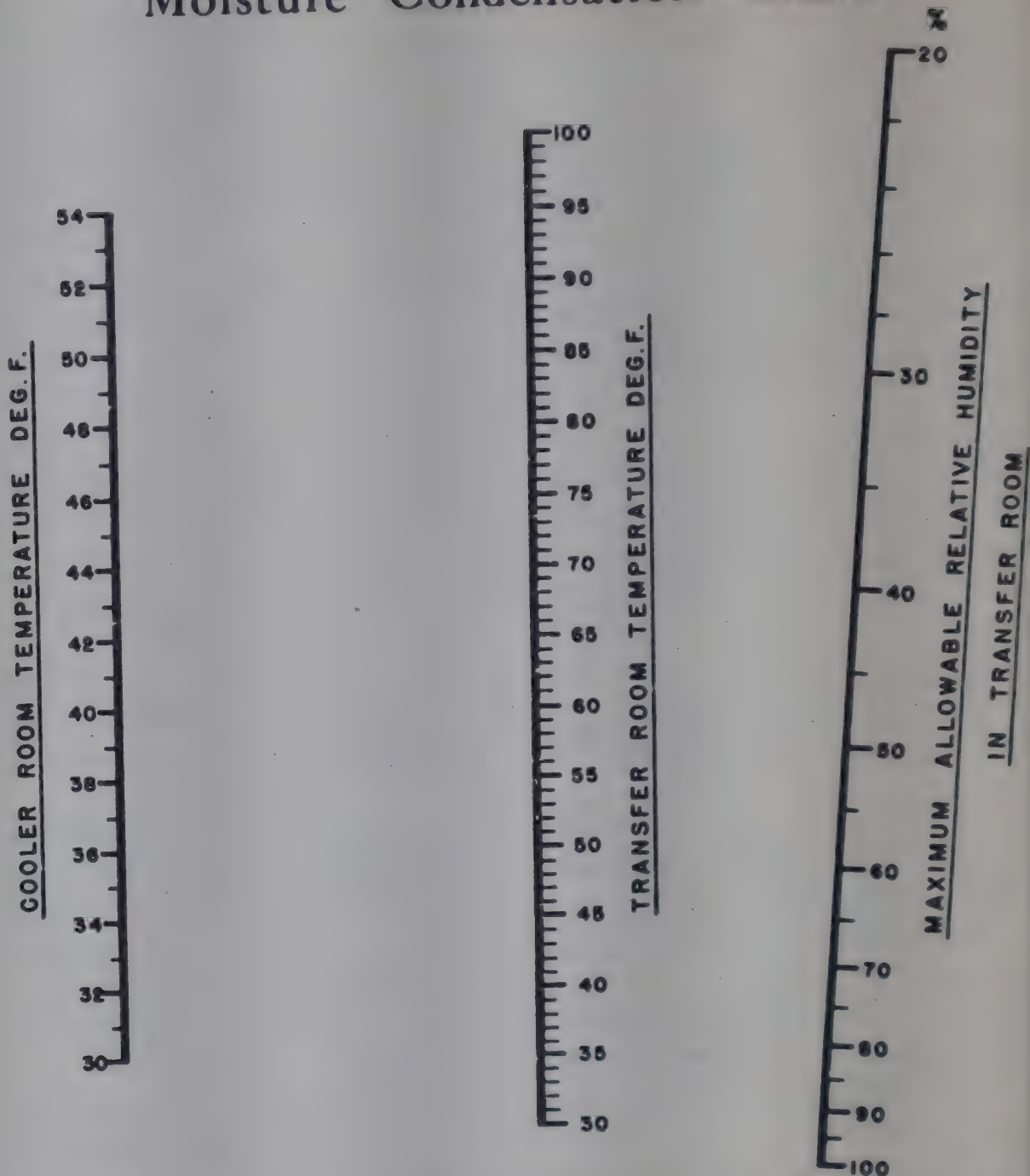


Figure 1. This chart or nomograph provides a simple, convenient method for avoiding condensation of moisture when moving cold operational ration containers to a warmer transfer room or area. Fiberboard containers and interior packaging materials can be materially damaged by moisture absorption due to condensation. This chart can be used to indicate quickly and accurately the maximum relative humidity that can be allowed safely in the transfer area before condensation will occur on the container surfaces.

TO USE THE CHART PROCEED AS FOLLOWS: (1) On the scale at the left, place a mark indicating the temperature in the storage area. (2) On the middle scale place a mark indicating the temperature of the transfer area. (3) Connect these two marks by a line and project this line onto the third scale. The maximum allowable relative humidity in the transfer area will be found on the third scale.

This chart may be used conversely. If after using the chart it is determined that the relative humidity of the transfer area is too high, connect this relative humidity on the third scale to the temperature mark on the middle scale. By projecting a line onto the first scale a warmup temperature for the storage area may be obtained.

Caution: If the relative humidity in the transfer area is higher than that found by use of the scale the containers should not be transferred until either the relative humidity of the transfer area is lowered or the temperature of the storage area is raised.

General Discussion

CHAIRMAN TRESSLER:

From now on, our conference is primarily a discussion. We have first a discussion of what additional information is required to establish optimum conditions for handling and storage of semiperishable subsistence items. We want to find out what additional work should be done in our own organization and by Dr. Woodroof in Georgia, since he is going to continue to work for at least 5 years in this field. If our plans are not drawn up so as to get the information you desire, we can change them.

The discussion will be introduced by Mr. Frank Rubinate, chief of the Subsistence Division, Container Laboratories, QMFCI.

FRANK J. RUBINATE:

We have talked thus far about operational rations. The thought was proposed that it might be advantageous to store components of rations and assemble them at a later date. Dr. Woodroof, in his presentation, indicated that in the work done to date there appears to be no problem of condensation on the cans when withdrawn from the refrigerated temperatures and higher relative humidities.

CHAIRMAN TRESSLER:

In the V-board containers?

RUBINATE:

Yes, in the regular V-board containers. In addition, cans used for overseas shipments, particularly for overseas rations, are coated with a corrosion-resistant lacquer on the outside. I would like to put this question out for discussion then: Should we consider the possibilities of storing by components, which then undoubtedly would be in domestic types of containers? The cans to be used for operational rations would undoubtedly be coated, but should we extend this to other than operational rations such as our B Rations to take advantage of the opportunity for longer storage and stockpiling? We would in many instances have bright, uncoated cans.

Dr. Woodroof, I wonder if you would have any comment on that in your experience with commercial items—whether the condensation problem has caused any trouble?

WOODROOF:

The problems of condensation on the cans and the product can be solved by "protective packaging," that is by (a) providing a waterproof barrier on the outer surface of the case which will cause condensed moisture to collect in drops and run off without penetrating the board, and (b) providing a moisture absorbing material about the cans or product, thereby preventing condensation. All military

rations tested were adequately protected from condensation by a combination of the above two conditions.

Most commercially packed canned foods are inadequately protected against condensation in that the cartons are not waterproof and there is not sufficient absorbing material around the cans. However, boxed candies overwrapped with cellophane or aluminum foil, and provided with soft tissue above the candy pieces, had no condensation. Likewise, commercially packed preserves in glass, packed with dividers, had no condensation.

There is one other comment on the components. I have been working on these for 3 years—and have a definite opinion about some of them. You have some components that are very perishable, like the cereal bars which require the best of temperature control and humidity control. Some of the cookies and crackers are very sensitive to humidity, particularly the sandwiches. Chocolate bars and most cookies are very sensitive to high humidities. Cocoa products and cheese, are a little less sensitive. It looks like all of these, by all means, will be worth refrigerating. There are other items such as the sugar which needs no refrigeration. We have never been able to find any benefit in refrigerating sugar. We have never found any change in flavor, moisture, or other factors in this item. As to the sugar, salt, can opener, toilet tissue, paper towels—we have had almost no response whatever. When you leave the latter out, you have reduced the number of items that need refrigeration to half. I have a very definite opinion about those that need refrigeration and those that do not need it.

RUBINATE:

That would indicate that such items, that should they be stored separately, would have to be packaged far in excess of what we would normally use for regular dry storage. That of course can be done by improving the type of pack and type of shipping container.

Dr. Kayan, I wonder if you would comment on your experience as to the possibility of rust and corrosion on bright cans that were stored in domestic types of fiberboard boxes, permitting a relatively free exchange of moisture vapor through the container?

KAYAN:

I would like to reiterate what Dr. Woodroof said, that the capacity of the container to absorb some of the moisture that forms may account for protection against rust or surface conditions in many cases. Certainly we cannot deny the formation of dew or precipitation when we get down to certain temperature conditions and, if it can absorb—and there is certainly evidence—(you and I are in wholehearted accord on that, Dr. Woodroof) the moisture may not show up on the actual contents as much as if they were out in the open.

DIEHL:

One of the reasons that the container is able to absorb some of the condensation is related to the control of humidity in the storage itself. Another factor is also involved. It is illustrated by the experience of a candy company which for many years stored candy in zero storage. They have never had any problem in condensation. They package their candy (and I am not advocating this for rations) in an air-conditioned room in which the humidity is controlled as well as temperature. Therefore, a desirable internal atmosphere of the case can be obtained in that manner. It can be obtained also by equilibrium in storage over a period of time. The quantity of moisture within becomes possibly so low that it is not possible internally to form a dew point in the temperature gradient that persists while the product in the case is taken outside and warmed to ambient temperatures. These two factors are very important. They both are attached to the matter of proper control of humidity within the storage itself. I recall in a discussion with your group in Chicago when it was revealed (and I think perhaps it is still true) that a 60 percent relative humidity was desired if the structural characteristics of this particular case were to be maintained. That humidity, or perhaps lower, to 50 percent, I think gives the environmental condition (both as to the case structure and the internal atmosphere of the case) which permits the case to absorb any possible moisture without any ill effects. It also has an atmosphere with such a low moisture content that a dew point is not possible in a temperature gradient. That is part theory, part experience, but is also to be further pursued by the group by definite empirical studies of the temperature, humidity, moisture, vapor deficit conditions, to be measured objectively by equipment. I don't know whether or not you have the entire equipment, but there is equipment for measuring the entire atmosphere for moisture content.

RUBINATE:

Mr. Diehl, you hit on the next question. At present, when we assemble rations or have rations assembled, we spread the activity across the country, concentrating on coastal areas close to shipping ports. In fact, we had one assembly down at Montauk Point, Long Island. Anyone familiar with that territory knows that in the month of August in the evenings, particularly, it gets very damp and humid. Now, should we take those rations, both the subassemblies including the B-unit, and then inclose and seal them in a can at those temperatures and ship them directly into cold storage it would seem to me that we are coming up to the problem which you have just pretty well outlined for us. We are entrapping, in that unit, air with a very high moisture content. Perhaps the only way to solve this would lead to another problem of controlling the areas of assembly. In that case, I would

wonder then if you have had any experience—those of you in the refrigeration field—with condensation and corrosion or damage due to condensation. The V-board box, as Dr. Woodroof pointed out in his report, does a very good job of keeping the moisture from going in or out if it is properly sealed.

MRAK:

Are you talking about tin containers?

RUBINATE:

Yes; primarily, those with which we have had rust problems, double-seamed cans.

MRAK:

I wonder if there would be any benefit in using a vacuum-sealed can.

RUBINATE:

Well, the number of units would be small. That would apply to the B-unit. I was thinking of the whole assembly, where it is accomplished in an area of high humidity and the humidity is sealed in.

MRAK:

I thought you were talking about the inside of the cans.

RUBINATE:

It applies in both cases. Of course, vacuum packing would be an answer to that except for the high cost.

MRAK:

It is used in every cannery. It is not a high cost procedure, is it?

RUBINATE:

Canners do not usually assemble a B-unit item.

MRAK:

The can companies have vacuum seamers as well as other types.

CHAIRMAN TRESSLER:

You are thinking of the external.

RUBINATE:

It is the B-unit that would be affected primarily. It is on the external area of the cans in a V-board container where your corrosion would be external.

CHAIRMAN TRESSLER:

It seems to me the answer to assembly in regions of high humidity is simply to maintain a dehumidified room for assembly, and dehumidifiers are now being manufactured by all the refrigeration people. Their cost is not great and, if they merely had the assembling done in a reasonably tight space with the doors closed, they should have no great

difficulty in maintaining a relative humidity of 50 percent or even lower. Such dehumidifiers on a small scale are available for damp basements and damp rooms now, and I am certain that for a couple of thousand dollars one could have a dehumidifier put in a room that would perhaps be double the size of these. They would be large enough for carrying out most of the assembly operation.

PENTZER:

I think you are straining at something here that is not as important as you think. At Fresno or in any climate where you have low humidity—humidity of 10 percent or 15 percent—you could look at the psychrometric chart and see when you reach the area of 32° or 40° F. Condensation within the package will occur even though you are packing in an area of low humidity. In other words, you are going to trap air in that package that will reach its dew point if you use cold storage temperature. My point is this. It takes a very small amount of moisture to saturate the air available in the container, and I think the internal surface of that package quite capable of absorbing the moisture present, even at high humidity. You see we never cool any fruit or vegetable. Every time you cool a package of grapes you have condensation in that package, but in storage it is taken up by the wood and by the air itself circulating past the package. I think, if you look at the psychrometric chart, you will find you are talking about a very few grains of moisture.

WOODROOF:

Our results agree with Dr. Pentzer's in that they don't quite check out as they theoretically should. He has stated that the walls of that carton have tremendous ability to absorb moisture or give up moisture, depending upon conditions. I raise another question—the practicability of putting in some supplementary materials such as desiccant. It might be cheaper to put in a little bag of desiccant than to air condition a whole room. We know it has been remarkably successful with potato chips and various other low moisture products. It may be that we can get a package of desiccant the size of a cigarette that would insure against any moisture condensation.

RUBINATE:

My purpose in posing the question was to see if all the people here thought that we had a problem of any magnitude.

FORESLINE:

I would like to point out that every product has its own vapor pressure characteristics and that those characteristics depend a great deal on what the moisture content is. Materials of very low moisture content have a tendency to pick up more moisture than products of higher moisture content.

I would like to toss out a thought in regard to bulk packaging. The reason I bring it up is that it has something to do with the package and something to do with cost. When I was with the Department of Agriculture, considerable work was done on cold storage with regard to the moisture content of the product, the relative humidity of the storage itself, and the protective package in which the product was packed. Since tin was not available, it was very advantageous to store in bulk.

Bulk packed products could be used for the assembly of rations. Products can be stored cheaper, handled more easily, and suffered less loss in a bulk container than in little tin packages. For example, 175 pounds of dried eggs packed in a lock-top fiber drum over a long period of time at relatively high humidity absorbed almost no moisture and maintained almost the same acceptability rating over a period of 2 or 3 years. By using small rooms and dehumidifying the atmosphere, we were able to reduce to 50 percent relative humidity and to use the ordinary commercial package. This offers two opportunities—either make a package that will not permit the moisture pick-up or reverse the situation and make the air so dry there will be little moisture to pick up.

Many ration items could be stored in bulk in their original condition and packed later. If something does go wrong and they do spoil, the packing and assembly has not been wasted. Mr. Appel, would it not be cheaper to store a barrel than it would the corresponding amount in small packages?

APPEL:

Yes.

GOESLINE:

In ration assembly we may have an opportunity to save more money by putting components up in bulk and packaging and assembling afterward.

WAGNER:

I am going to try to broaden the horizon a bit and take this question quite literally: What additional information is needed to establish optimum conditions for handling and storage of semiperishable subsistence items?

Yesterday we agreed, or at least a number of people agreed, that the word "semiperishable" ought to be dropped. So the problem is: What additional information is needed to establish optimum conditions in the handling and storage of subsistence items? Dr. Mrak made clear yesterday that if we undertake such a broad question that there are at least four different approaches which should be considered. One is to

develop a superior ration item. The Quartermaster Food and Container Institute at the present time has a very active research program in that area, and, in my personal opinion, it is quite productive. Secondly, it is to collect information on and to control storage conditions. This meeting so far has been concerned almost entirely with that aspect. Mr. Rubinate has brought out some additional points not covered by the papers. I think if anyone else would care to volunteer, this would be a good place to do it.

DIEHL:

In regard to Mr. Appel's remarks about the practicability, in the operational sense, of a 40° or 45° F. temperature, there is also something else to be considered—that the temperature range from the freezing point of the product to 40° F. is a very important one. Many researches are done at 40° F. rather than in the range between 40° F. and the freezing point. The degrees between 0° and 40° F. are very much more important than those at higher ranges. Therefore, for real effectiveness as well as practicability, studies in the future that involve reduced temperatures should, I feel, not neglect the temperatures around the freezing point of the product itself. I think that often is ignored; the higher temperatures are selected for some reason of which I am not aware.

WAGNER:

Another question was brought up yesterday in connection with Dr. Mitchell's paper. You may recall that the rates of deterioration in his products at 40° and at 70° F. were very similar. I would like to ask Dr. Mitchell if it makes any difference whether those products were held at 40° or 70° F. or cycled in that range?

MITCHELL:

With some products we have examined, apparently the rates of deterioration at 40° and 70° F. are close together. I think the evidence has shown that in some cases they are widely different and that more stability is achieved at 40° than 70° F. In regard to cycling, there are innumerable conditions that one could choose, but so far we have not done cycling work. We are simply first trying to establish landmarks. I might add, too, that I feel that we need 2 types of stability studies—to provide information first on stability of rations packed as they are to be assembled for use overseas, and secondly, on certain items packed separately. In that way only will we learn the stability of the individual item, and in that way only can we determine the cause of its instability. We have to know whether it is the item itself, the item as influenced by something with which it is packed, or the container.

LT. COLONEL ROY C. BAKER (Office of The Quartermaster General) :

After we store these rations for 4 or 5 years under controlled conditions and they are brought out, how soon will we have to use them? I think it should be clearly understood, especially with something like a combat ration, that you are not going to have it under refrigeration up to time of consumption. Has there been any research on the time element in our phase of operation, and how long would that time element be?

CHAIRMAN TRESSLER :

In general we are considering the rate of deterioration to be four times as fast at common storage as at 32° F. If you store at 32° F. for 4 years, that is the equivalent of 1 year's common storage. If the product has a common storage life of 2 years, half of the storage life would be gone. You have then 1 year in which to use that item before it becomes definitely inferior. Even allowing for the exceptional cases, I think you have to work on such an assumption; otherwise, it would be next to impossible to prophesy.

APPEL :

Yesterday, Dr. Mitchell in giving his paper used the two temperatures—70° and 40° F. I would like to ask him two questions. Is there anything objectionable in your opinion to 30° or 32° F.? Would ordinary commodities be better or less good kept at 32° as against 40° F.?

MITCHELL :

There isn't anything particularly sacred about 40° F. We have attempted to cover a wide range of temperatures normally encountered in Armed Forces storage conditions. Since 100° F. was selected for the high temperature, equal spacing resulted in the selection of the two other temperatures of 40° and 70° F. Aside from that I don't think it makes any difference whether we store at 40°, 30°, or 35° F. Once we get enough points on the curve, we can interpolate between them. Maybe we cannot project, but we can interpolate with some degree of accuracy. In this manner we may eventually be able to predict the probable keeping time at the various temperatures encountered in supply situations.

CHAIRMAN TRESSLER :

Isn't it figured that at 32° F. rations will keep for somewhat longer than at 40° F.?

MITCHELL :

Based on the theoretical ideas of chemical reactions, they would.

CHAIRMAN TRESSLER :

Very definitely, you can keep a given vitamin content approximately 25 percent longer at 32° than at 40° F.

APPEL:

I asked the question for a very definite purpose. I think it would be a mistake if some stranger read the record of this meeting because continuously there is a repetition of 40° F. In my opinion, there is nothing magical in 40° F. It is being used in experimental work. I am glad of that answer and I am glad, Dr. Tressler, to hear your comment, because it is our practical opinion that in all cooling matters the lower you can carry the commodity without freezing it, the better you keep it.

KAYAN:

Is 40° F. a conventional commercial storage temperature?

APPEL:

Not at all. The nearest to it would be 35° F. Even 35° F. is off. Commercially, of course, there are a few items we carry at a higher temperature, 45° or 50° F.—candy, potatoes, and some cheese. But actually those temperatures are not by any means regularly used. The great mass would be around the freezing point.

GORESLINE:

During the war it was decided that dried eggs would have to be refrigerated, and when the suggestion was made to use 32° F. there was objection that space would not be available. I don't know from where it came but it was decided that 50° F. temperature was available. Fifty degrees was picked as the maximum storage temperature and is in the USDA specifications for storage. This was on the basis that it was available and that it cost less than the 32° F. storage. I think one reason for choosing these higher temperatures was the belief that they were available and would be cheaper. If that is not true, I certainly would like to be corrected.

APPEL:

I think you said a moment ago that at that time you were at the Department of Agriculture. If you inquire of the Department of Agriculture you will find that it came from them and not from the cold storage industry. Actually, I remember the 50° F. and I also remember that many of us objected.

CHAIRMAN TRESSLER:

Further, isn't it a fact that with the exception of the apple and potato storage there is more storage space in the neighborhood of 32° F. than any other type?

APPEL:

That is correct.

CHAIRMAN TRESSLER:

That is the important point, and I feel if these products are to be kept under refrigeration we should give them the maximum protection, which is 32° F. The additional cost between the higher storage and 32° F. is negligible.

WAGNER:

May I interpret your remarks to mean, therefore, that if we are to consider the future application of this work, we should know or at least be able to predict what is going to happen under 32° F. storage, because that temperature may possibly have to be used?

CHAIRMAN TRESSLER:

Yes.

MITCHELL:

I would like to amplify my remarks and try to explain why we use 40° F. When we started this study, there was no idea of storing these items under refrigeration. We are conducting our studies because, even though they may be refrigerated at some point during storage they will be subjected to long periods of nonrefrigerated storage in use. We are trying to get information enabling us to predict their storage life or stability under military conditions, and when you look at it in that light we need a number of different temperatures in order to arrive at that information.

MAXWELL:

Admittedly, there will be operational rations in refrigerated storage. We must maintain fairly substantial reserve stocks in the overseas theaters. So in any studies and developments with respect to the life of the ration, the thought should be borne in mind that a substantial portion of any of our production must be placed in overseas reserve stocks. They will have to be ready to go the minute the whistle blows.

Now, relative to the storage of the components of the ration vs. storage of the assembled rations, we must again have a substantial quantity of rations completely assembled. They have to be at a port in a minimum of time—say 30 days. Whatever the time may be that is required to take these unassembled rations, assemble them, and deliver them to a port—that is the lead time. We must have adequate stocks to support a given strength that can be moved to the port on a minute's notice and possibly in refrigerated storage. Those are two points I would like to emphasize.

WAGNER:

If someday someone is going to have to make an administrative decision as to how this is going to be used, I think those people—who, I am assuming, include yourself—will want to know everything they

need on which to base a decision. Therefore, I think it appropriate to have from you any further comments on what is lacking in the present program on what is needed for making a decision.

MAXWELL:

You mean detailed information on quantities in the overseas areas being required for immediate movement to the port?

WAGNER:

Will the present program provide a basis on which to decide whether to use cold storage or not?

MAXWELL:

I don't quite understand your question. Actually, at present we have firm information as to the reserve overseas stocks—actual information as to the quantities to be at the port in given periods of time. Our present stocks of rations on hand, as you know, comprise largely our 1951 pack rations with a small quantity of 1952 assembled rations. We do at present have a procurement request in for the purchase of additional quantities. Now, a determination will have to be made whether they should go into refrigerated storage immediately upon assembly. In the present plans, it seems a portion of that quantity must go immediately to overseas storage. At present the stocks in the overseas theaters are 1951 pack. We will undoubtedly ship some 1952's to them to maintain a progressive rotation of overseas stocks. If we should ship 1954 or 1955 pack rations as they come off the line, a determination will have to be made as to what quantity should go into refrigerated storage.

WAGNER:

One more point brought out yesterday hasn't been discussed. I want to reiterate—during the storage of rations, whether common or cold storage, there is the problem of surveillance and inspection. There is indication that the present system in effect does not provide a basis to determine forced issue and salvage, and contains very little element of prediction under which one can anticipate far enough in advance the need for issue to avoid issuing rations which have achieved low acceptability.

Major Fischer mentioned in his talks that forced issue was a very unpopular practice with the consumer, and from what I have seen of some of the rations which I understood were going into forced issue, I can understand it. It seems to me some consideration ought to be given to reviewing surveillance and inspection to determine what can be done to improve it from the standpoint of giving better information as to condition, and also to provide a basis for predicting further in advance that it is going to go bad before it actually goes bad.

C. B. ALLEN (Office of The Quartermaster General) :

At the outset, I would like to say that the material presented here will help us greatly in performing our mission, which is in part to receive, store, and issue subsistence. We have learned a good bit, of course, the hard way, with our cherries popping and the tomato puree. Sometimes a section might resemble a slaughterhouse or something to that effect, but we do feel that the subsistence timekeeping tables in TM 10-250—and, incidentally, there is a supply right outside the door—do need revising and to be brought up-to-date. I think it might be well to put that in one manual—with reference to 10-250—that would help us considerably. That list, of course, is too long to discuss here, and there are several ramifications in here as to type of pack and location. We do check subsistence upon receipt, and we keep it constantly under surveillance until the time of issuing. This is primarily a visual inspection. If we see a flipper or sweller, obviously we are not going to issue that stock; and we also have laboratories which are readily available with trained personnel, too, so that we can select a sample from the stock when we know that the keeping time is about exhausted or running out. We have picked up some tomatoes and various other items and gotten them to the point of issue before they were spoiled. And, of course, those timekeeping tables are very important, because the inspectors watch those very carefully. So anything that can be done on that to put it into a consolidated manual would help us. I might add, you cannot put in there too much technical information. Let us have a good manual—not just simply the comments we have now. Of course, that helps us considerably, but if we had any additional information in there so that we can do a better job, we can save the Government money; and when we issue subsistence to the troops we can feel reasonably sure that it is going to be declared fit for human consumption when it gets there. We do not make such a declaration at the depot. We only determine: Is this item suitable for issue? It is up to The Surgeon General's people to make the determination at the point of consumption.

WAGNER :

I wonder in your experience how well the predicted storage life, according to the manual, has corresponded to the actual experience with storage stocks?

ALLEN :

Offhand, I would say that it is fairly accurate. However, there are some items that are not in there. Much depends on the condition of the stock item when it is received. Sometimes the canned goods will have undergone sweating, and then we have to violate one of our cardinal rules and not ship out the first-in first-out. We go ahead and get

that stock into issue in preference to some of our older stock we might have on hand. I might add, too, as far as insect infestation control is concerned, we do have, as you know, vacuum fumigation equipment at all of our depots, and we have found that this equipment has certainly more than paid for itself over a period of years. Then there is available to us an entomologist on the staff of the engineer of each Army area, and we use his services to good advantage.

WAGNER:

One other question: Do you compute your period of storage from the date of pack or from date of receipt?

ALLEN:

Date of pack. That is the date we use.

CHAIRMAN TRESSLER:

Colonel Peterman, do you have any comments?

COLONEL JOHN D. PETERMAN (Quartermaster Food and Container Institute):

My comments are going to be very few. Of course, it is dependent on the Food and Container Institute to consolidate this information and present it to the Quartermaster for information. But I would like to mention one point here—the temperature of 50° F. I think that temperature goes back to the time when we were thinking about underground storage of military items. The only logical or available place was out in Kansas in the cave out there, and the temperature that was available was 50° F. So that is why 50° F. was accepted at that time. The Institute later went lower, down to 40° F. but just to see what we could come up with at 40° F. We can go much lower now and we should make some studies at the lower temperatures.

I want to add my thanks to all the participants in this symposium. It has been most successful.

RALPH SIU (Office of The Quartermaster General):

Like any other perplexing problem, a most definite phase of research and development activity is really the definition of the problem—a clear definition of what exactly is the problem. And in this case we have a total problem which is: What should the Quartermaster Corps do with regard to its practices in storage? That problem involves many ramifications in distribution practices, procurement practices, the availability of foods in different parts, strategic concepts, and so forth. So we cannot hope to even frame that particular problem without an awful lot of examination and analysis. This is not only an Institute but a Quartermaster Corps operation in research analysis. Now, if you break that big problem down into your subproblems, then you have some problems which the Institute itself can handle, and it

also has to analyze the specific problem. Then if you take the ramifications of the storage problems and consider its implications on the rest of our research program, you find you might have to go to a contract testing the nutritional adequacy of the ration. A lot of those programs are based on testing the adequacy of a fresh ration, and that means that your own nutritional data is not too reliable because the nutritional adequacy of a ration should be tested on the basis of a ration as delivered after these damaging storage conditions.

I appreciate the invitation to be here, and I think the next step really is the analysis and framing up of the specific problem. Then, after the Quartermaster gets that, it can go out again for additional help or other conferences.

CHAIRMAN TRESSLER:

I wish personally to thank each and every participant in this particular symposium, especially the ones from outside the Quartermaster that have made this possible.

With that, the meeting is adjourned.



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